USABILITY TESTING OF A DIGITAL PEN AND PAPER SYSTEM IN NURSING DOCUMENTATION

by

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CERTIFICATE OF APPROVAL

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Abstract

The first step to achieve all the benefits of an electronic medical record is accurate entry of clinical data. Most existing technologies for data entry by clinicians have significant disadvantages. The digital pen and paper system is a new technology which may be the most suitable documentation device for hospital nurses. In this study, usability testing was used to evaluate whether the digital pen and paper system would be usable for hospital nurses. The study was conducted in the Labor and Delivery unit of an urbane academic medical center. Twenty-one nurses volunteered to take part in the study, in which they were randomly assigned into 2 groups. Using a crossover design, Group 1 used the digital pen and paper system for the first four weeks while Group 2 used the conventional pens; in the second four weeks, the groups switched the devices. Data collection included observations by the investigator, interviews with the participants and a questionnaire. The study found that nurses could foresee the potential benefits of the digital pen and paper system, but they found the system in its current form had poor usability and interfered with their work process. Bennett's model was used to help explain these findings in terms of the interaction of user, tool, task and environment. Usability testing gave important insight into the needs of nurses and the suitability of this technology. This study is an example of how a user-centered approach can improve our understanding of the real needs of nurses and contribute to the design of useful and usable technologies for healthcare.

1. Introduction

1.1. Background and Significance

Clinical information systems offer important benefits to healthcare, including decision support, knowledge management, improved communications, effective resource management, reduction of medical errors, as well as saving time and reducing paper work (1). Nursing information systems are among the key components needed in a comprehensive hospital information system if these benefits are to be realized. Beyond documentation and entry of clinical data, nursing information systems help nurses to organize their work, manage nursing care plans, track diagnoses and outcomes, and support decision-making. All of these functions depend critically on absolute accuracy of the data entered in the electronic health record. Therefore, the first step to quality nursing care is to improve nursing documentation and data processes (2).

However, computer supported data entry may be problematic, not only for nurses, but also for most clinicians. While most research focused on physician order entry and physician interaction with clinical information systems, less attention has been paid to the obstacles that arises with nursing documentation and data entry. The goal of this research is to better understand the interaction of nurses with clinical information systems focusing on the technologies available for nursing documentation and data entry.

1.1.1. The Problems

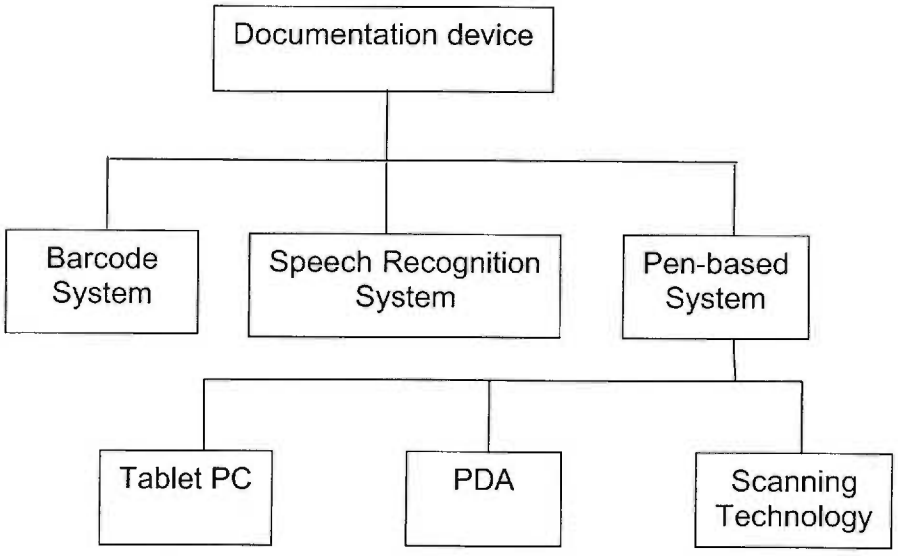
As state above, nursing documentation and data entry are essential elements to quality nursing care. However, existing technologies for documentation and data entry are problematic. Most interaction with computers requires the use of a keyboard and a

mouse, but these devices are poorly suited to most clinical work. As a result, paper and pen continue to be the preferred tools for recording clinical data for the majority of physicians and nurses. It is commonplace to see clinicians carry paper and pen while collecting data on the wards, only to transfer this information into another information system, which results in duplication of effort. Thus, ideally, a new technology should provide the ease of use as paper and pen with limited disadvantages.

1.1.2. Possible Solutions

A number of new technologies have recently been developed to assist clinicians with clinical documentation. These include barcode systems, speech recognition systems and pen-based systems, all of which can be subdivided into three categories: Tablet PCs, Personal Digital Assistants (PDAs) and scanning technology (Figure 1). However, these systems may be inferior to nurses because of the characteristics of nursing work. Following is a brief discussion of each of these technologies.

Figure 1. Documentation technologies



1.1.2.1. Barcode System

Barcode systems are widely used in clinical laboratories, because they improve efficiency and accuracy of data entry. Barcode systems not only increases the speed of data entry, but also reduces errors and is well accepted by users (3). In nursing, barcode systems are widely used for patient medication administration to improve patient safety. Nurses scan the medication barcode and then scan the patient wristband barcode to ensure correct administration, which automatically creates a record. This reduces medication adverse events by the "five rights" principle of drug administration, saves time for nurses and reduces costs for hospitals (4, 5). Barcode systems are best suited to data entry tasks with highly structured data and few data elements. However, nursing documentation often includes rich clinical information about individual patients that is not easily managed by a barcode system.

1.1.2.2. Speech Recognition System

Speech recognition systems have been especially instrumental for clinical tasks such as surgical dictation, radiology and pathology reporting where vocabularies are limited. Expression can be standardized with speech macros, and the dictation tasks are usually performed in an isolated, dedicated workspace (6). However, speech recognition is much less suitable in noisy public spaces. For instance, a nursing station has frequent background noise, which interferes with speech recognition, causing the confidentiality of patients' health information to be threatened. Furthermore, it has been reported that speech recognition systems take more time in correcting. Despite the speed of speech recognition, the total time to complete the data entry task may be greater (7).

1.1.2.3. Pen-based Systems

Pen-based systems, as the name suggests, are data entry systems that use pens as the main tool to record data. Pen-based systems include Tablet PCs, PDAs and scanning technologies. These systems allow users to employ a pen as a familiar device to capture data in an electronic system, either with handwriting recognition (Tablet PCs and PDAs) or without it (most scanning technologies). It has been reported that the use of a pen imposes a lower muscle load than a mouse when performing a drawing task. This allows users to pinpoint a location with greater precision and is associated with lower error rates (8).

1.1.2.3.1. Tablet PC

Tablet PCs are meant to provide the benefits of pen-based entry with the power of a computer and a large display area. Ideally, using a portable Tablet PC allows clinicians to carry them during patient care. In addition, greater storage capacity or wireless connections allow for decision support that is available where needed. Tablet PCs can be used for either structured data entry, handwriting recognition of free text, or writing and drawing without handwriting recognition. However, the weight and the fragility of Tablet PCs creates significant limitations which reduces their acceptability to nurses (9, 10).

1.1.2.3.2. Personal Digital Sssistant (PDA)

Another potential solution is the PDA. Like the Tablet PC, PDAs take advantage of the familiarity of the pen, but have greater portability because of their small size and weight. These features have led to widespread general use for tasks such as personal information management. However, their small size also leads to limitations: users

complain about the small screen size, which can only display a small amount of information and is difficult to read and enter free text. Furthermore, in a data collection task, excessive scrolling is required to complete a long questionnaire, which is often necessary in medicine. More than half of users believe PDAs are not easy for typing or writing (11).

1.1.2.3.3. Scanning Technology

The trade-off between small size for portability and large screen for readability is a difficult choice. This may be why paper remains the preferred choice among clinicians. Scanning technology offers a compromise; it combines the portability and readability of paper with the benefits of electronic storage, distribution, and display, while eliminating duplication of data entry.

With scanning technology, clinicians create the usual documents with pen and paper. These documents are then scanned into the electronic health record with or without optical character recognition. Either way, duplicate data is eliminated and the clinical information can be stored, distributed and displayed where needed. However, there is usually a delay between the creation of the documents and the scanning process, which reduces the potential benefits (12) Furthermore, unless optical character recognition is used other benefits of the computer-based patient record, such as data search, retrieval and analysis can not be realized (13).

Each of these devices has significant limitations. What is needed for nurses is a technology that combines the technological advantages without their shortcomings. One such technology, the digital pen and paper system, has these features and may be a suitable solution for nursing documentation.

1.2. Digital Pen and Paper System

A digital pen contains five parts: 1.) a digital camera, which continuously tracks the position of the pen relative to the paper; 2.) memory, enough for approximately 50 pages of A4 or letter size paper; 3.) an ink cartridge, like a conventional pen, enabling users to see what they have written or drawn; 4.) a force sensor, which detects the user's writing and starts recording; 5.) a battery.

Figure 2. Digital pen

The digital paper contains an array of 0.3mm dots printed with slightly off-white color that can be carefully seen with the naked eye. These dots enable the camera to track the location of the digital pen relative to the paper within a virtual space equivalent to 60,000,000 square kilometers. As the user writes with ink on the digital paper, a digital representation is created in the memory of the digital pen. This representation is then transferred to a computer at a later time. Lately, a paper representation and an electronic representation are created simultaneously. One such digital pen and paper system is developed by Anoto, a Swedish firm (14), available in the US through Logitech among others.

Once a digital representation of the user's writing has been created, a recognition process must be used to make use of the data. One solution to this recognition problem is

a highly structured forms-based approach. Commercial systems are available which use this approach to improve the efficiency and effectiveness of data collection in conjunction with mobile devices like Tablet PCs, PDAs and Signature pad, as well as the digital pen and paper system.

1.3. Usability Testing

"Usefulness" and "usability" are terms often used when researchers want to define whether a technology is appropriately designed for users. These two words seem similar and easy to understand. However, conceptually they are quite different. Shackel defines the terms in this way, "useful means advantageous, profitable, fit for some desirable end, or having power to satisfy human wants, while usable means able to be used, applicable to a purpose" (15). For evaluating clinical information systems in practice, we expect information systems not only to be "useful", but also to be "usable". However, though "usability" is a widely used term, there is no widely accepted definition (16). Different definitions are offered by different scholars. Thus, it is important to define "usability" clearly before we start the evaluation of a product's usability.

1.3.1. Definitions of Usability

"Usability" is primarily found in the field of Human Computer Interaction (HCI) where it is described as the relationship between humans and computers. According to Staggers, nursing computer systems should be designed with an understanding of human-centered attributes and cognitive behaviors so that human computer interactions will seem natural, achieving the goal of computers as "assistants" to humans (17). However, the usability of a computer system is determined not only by the user-computer

interactions, but also by the degree to which it can be successfully integrated to performed tasks in the intended work environment. While usability is a user-centered design attribute, the human-computer interaction is not the sole evaluation focus. It would be more accurate to say, as Bennett has proposed, that usability is developed through user-centered design methods but measured through the interaction of user, tool, and task in a specified setting. Therefore, the meaning of usability should contain four major components: user, tool, task and environment (18). Four different but similar definitions of usability are listed below (Table 1).

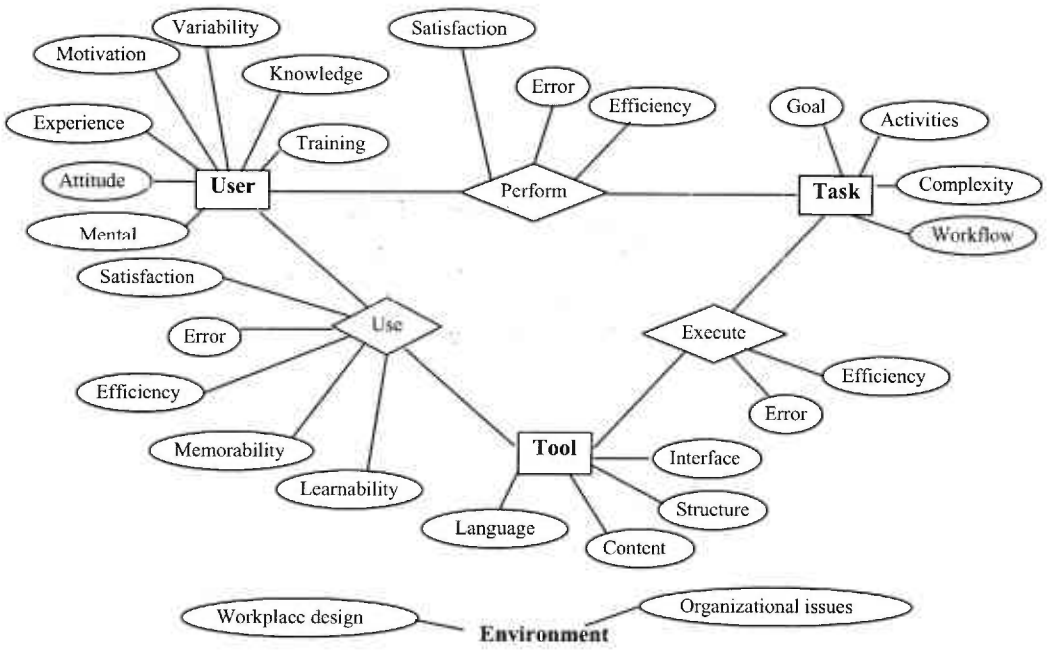
Table 1. Definitions of usability from different scholars.

Sheckel (1984)	"the capability to be used by humans easily and effectively" (19)
Bevan et al (1991)	the usability of a product as "a function of the particular user or class of users being studied, the task they perform, and environment in which they work" (20).
Nielson (1993)	Usability with using five attributes: learnability, efficiency, memorability, errors and satisfactions (19).
ISO 9241-11 (1998)	the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (21).
Dumas et al (1999)	usability is observed when "the people who use the product can do so quickly and easily to accomplish their own tasks" (22).

In this study, Staggers' model, which has the advantage of specifically addressing human-computer interaction in the context of nursing (23), has been extended by combining it with Bennett's model, which also recognizes the importance of the task and the setting within which it is performed. Thus, we may reframe the definition of usability as shown in the Figure 3. Usability is a set of relationships among user, task, tool and

environment, each with its own attributes, interacting with interdependency upon each other.

Figure 3. A framework, modified from Bennett, for understanding usability. The figure illustrates the four main components: user, tool, task and environment; selected attributes of these components (for example, the goal, complexity, and activities of a task at upper right); and the relationship between the components (for example, a user *uses* a tool.)



1.3.2. The Significance of Usability Testing

Usability testing is a method for identifying specific problems with usability of products, and it can be used to improve their usability (22, 24). The benefits include

improved predictability of the products, greater productivity with fewer user errors, and savings in development time and cost (19, 22, 25).

Usability testing may be conducted in different stages of product development, depending on the purpose (22). For instance, when building a new system, early usability testing can be used to identify problems before substantial investment is made in inadequate design. It would be better to build a new system where previous concerns about the problems would be addressed (24). Using an iterative and comparative usability test during the development of products makes the product more and more specific to users' needs (26).

Nursing Information Systems (NIS) has been developed to help nurses. However, several problem were found in nursing information systems, including "No systemic research in the area of NIS development and evaluation" (27). In order to improve information systems, usability testing for nurses as a specific class of user is critical to understand what the difficulties nurses face.

1.3.3. Usability Test in Nursing

It follows from the previous discussion that usability testing ideally examines the relationship of users, tools, and tasks in a specific working environment. However, most studies of usability of nursing information systems focus on single measures such as task completion time (28-31). This seems reasonable given the complexity of nursing work and the importance of time efficiency. But published reports show that time savings alone is not the whole picture.

As Bradshow reported, the motivation to adopt nursing information systems is often to increase time for direct patient care (32). It has been shown that nurses spend

roughly 1/3 of their time in direct patient care (33), and nurses expect that nursing information systems will free up more time for direct patient care (29). However, nursing information systems are not always designed with this goal in mind (27).

Two studies reported that use of nursing documentation systems did not increase direct patient care time (32, 34). In fact, other investigators have shown that the time saved by using nursing documentation systems is allocated to non patient care tasks (31), or to non-productive tasks such as waiting for terminals (35).

Thus, as Urden has stressed, studies must examine not only nurses' documentation time, but how nurses allocate their time among all tasks and activities (33). These studies have focused on only one important aspect of usability, but in order to improve the usability of nursing information systems, it is necessary to see the whole picture. The present study examines usability of a documentation device with the digital pen and paper system, using this broader, more comprehensive approach, which includes users, tools, tasks and the actual working environment.

2. Research Question

The goal of this study is to determine the usability of a digital pen and paper system. It follows from the previous literature review that all four components of usability, users, tools, tasks, and working environment must be addressed for a comprehensive evaluation of usability. In this study, the users were labor and delivery nurses; the tool was the digital pen and paper system; the task was completion of a standard admission form; and the environment was the Labor and Delivery unit of a modern university teaching hospital. Using a combination of methods, the study sought to answer these questions:

-What are the advantages and disadvantages of the digital pen and paper system?

-What attributes determines the usability of the digital pen and paper system?

3. Hypotheses:

Conventional pens are familiar tools, which nurses have traditionally used for documentation tasks and are the natural comparison for the digital pen and paper system. To be successful, the digital pen and paper system must have usability that is comparable to conventional pens. This can be stated in the form of the following hypothesis:

Hypothesis 1: There is no preference for digital pens or conventional pens. The digital pen and paper system is not more difficult to use than conventional pens.

The study uses a crossover study design where the subjects are exposed to the experimental intervention in a different order, for controlling a potential order effect. However, this introduces the possibility of recall bias due to the timing of exposure of the intervention. To test for this bias, a second hypothesis can be stated:

Hypothesis 2: There is no time effect. The perceptions of subjects with early exposure to the intervention will not differ from the perceptions of subjects with later exposure.

4. Methodology

4.1. Research design

To address this question in a comprehensive manner, three strategies that provide complementary information are used: observations, interviews, and a crossover study using post-intervention questionnaires. Observations provide objective information and greater insight into the work processes. Interviews provide the informed perceptions of

insiders, and questionnaires in the crossover design provide data for quantitative comparison. All three strategies were used to examine hypothesis one, while a crossover design was chosen specifically to test hypothesis two.

4.2. Users – Population and Sampling

The population of interest in the study is hospital nurses. Because an obstetrician on the medical staff had an interest in this technology, the Labor and Delivery unit was chosen for the study. This unit has 65 nurses, ranging in age from 26 to 58 years (mean age 45 years). Nurses had worked on this unit for between 0 and 30 years (mean 10 years). The manpower of each shift is approximately 9 nurses on day shift, 8 nurses on evening shift and 7 nurses on night shift, but staffing is adjusted according to patients' acuity.

The sampling aim was to include nurses working more than 0.5 FTE, with representation from all shifts: day shift, evening shift and night shift, to account for possible discrepancies in work practices on different shifts. A convenience sample of volunteers was recruited with an attempt to include representation from each shift.

After obtaining the approval of the nurse manager, who agreed to support the study and help recruit subjects, recruitment information was posted throughout the unit for one month. Nurses were then recruited by attending informal events on the unit, such as breaks, dinner, and change of shifts. At each event, a fact sheet was provided, the study was explained, and nurses could ask questions and give verbal consent to participate. Human subjects' approval was obtained from the Institutional Review Board prior to recruitment or data collection.

Twenty-one nurses agreed to enter the study. Using a random numbers function, nurses were assigned to one of two groups. Group 1 used the digital pens for the first four weeks, then conventional pens for the final four weeks. Group 2 used conventional pens for the first four weeks, then the digital pen for the final four weeks. Recruitment procedures were adjusted to achieve approximately equal group sizes and representation from all shifts.

4.3. Tools -- Intervention

The intervention in this study was the use of a digital pen and paper system, adapted to meet requirements of the Labor and Delivery unit documentation. The digital pen chosen for the study was developed by Anoto and manufactured by Logitech (Logitech, Inc., Fremont, CA) (36), and provided by Mi-Co (Research Triangle Park, NC) (37), which also produces digital paper forms (Mi-Forms) customized to organizational needs. The digital pen communicated with the computer through a cradle – cable attachment, rather than a wireless connection, as illustrated in Figure 4.

Figure 4, Logitech io Digital Writing System (Logitech, Inc., Fremont, CA).

Nurses were provided with their own pens for the duration of a shift so that they do not need to obtain or share the device, which eliminates interruption. The digital pen can also be used to write on regular paper, eliminating the need to switch from one device to the other. On only two occasions, there were not sufficient digital pens and an intervention group nurse was required to use a conventional pen for that shift. Otherwise, nurses used the assigned devices, not only for completion of the digital forms, but also for regular use.

4.4. Tasks

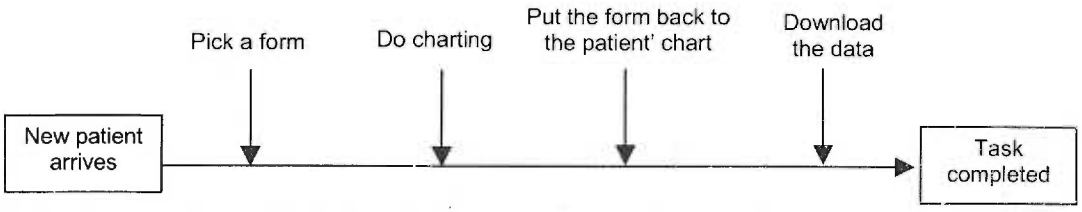
Nurses in the Labor and Delivery unit use several paper forms to collect patient health information. After discussion with the nurse manager in the unit, completion of the "Admission Database" form was chosen as the task for evaluating the digital pen and paper system. The "Admission Database" form includes information such as identifying data, medications, medical history, immunization, habits, diet, and activities of daily living function, psychological situation and learning pattern. This task was chosen because it is a common task, using a familiar form of only two pages. More importantly, this task is always completed by a single nurse while other forms may be worked on by multiple nurses.

Once this task was selected, the Admission Database form was submitted to the digital paper supplier (Mi-Co) to build the customized digital version of the form. The customized version of the admission form was virtually identical to the original, thus preserving the nurses' familiarity with its format and content.

Figure 5 illustrates the expected workflow for Admission Database form completion using the digital pen and paper system. When a new patient arrives, a nurse,

who already carries a digital pen, must obtain a blank digital form, and takes it to the patient's bedside where she obtains information from the patient to complete the form. Once the form is completed, the nurse must add the form to the patient's chart as usual. The digital pen must later be return to the cradle at the nursing station to transfer the data into the computer but this can be done at any convenient time. This expected workflow does not include interruptions or distractions, which may occur in a typical Labor and Delivery unit. However, such interruptions are equally likely to occur with both conventional and digital workflow.

Figure 5. Idealized workflow



4.5. Task Environment

The study was conducted in a moderately busy Labor and Delivery unit in an academic medical center with a diverse patient population, including patients with comorbid conditions threatening delivery. The goal of the ward is to facilitate a birth experience that is smooth, safe, comfortable and memorable. Nurses provide support and monitoring during active labor, assist with delivery, manage the complications and provide postpartum health information and breastfeeding instruction. The pace of activity can range from relatively quiet to hectic, emergent management. The computer setting of the digital pen and paper system was illustrated in Appendix A.

4.6. Data Collection

4.6.1. Instrument 1: Questionnaire:

The questionnaire for this study was developed by combining items from two existing and validated instruments. Items concerned with usefulness and ease of use were drawn from the Technology Acceptance Model (TAM) developed by Davis (38), while items concerned with task compatibility and users' attitudes were taken from the Perceptions of Adopting an Information Technology (PAIT) questionnaire developed by Taylor (39) based on the work of Moore (40).

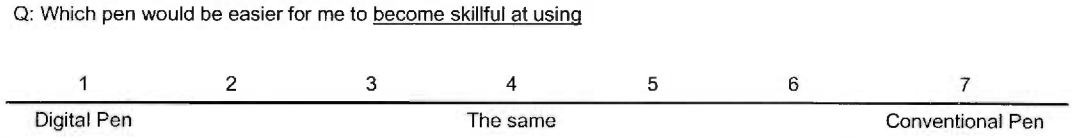
The reliability and validity of the TAM questionnaire has been demonstrated in several studies. Morris, referring to its use in general computer technology assessment, found that "TAM is an efficient and cost effective tool for predicting end user acceptance of systems" (41). TAM has also been used in healthcare technology assessment. Ammenwerth reported a Cronbach alpha of .93 in a study of the acceptance of a report writing system used by physicians (42).

The TAM questionnaire addresses the relationship between user and tool. To obtain a more complete picture consistent with the Bennett model, additional items were added to address their relationship to the task. These items were drawn from the PAIT questionnaire. The final instrument used in this study incorporated four factors including perceived usefulness, ease of use, compatibility and user attitude. The reliabilities of these measures were: perceived usefulness, .98; ease of use, .94 (both by Cronbach alpha (38)); compatibility, .82; and attitude, .85 (both by Guttman's Lower Bound (39)).

The final questionnaire consisted of 19 questions using a seven-point Likert scale (Appendix B). Items from the original questionnaire were worded to evaluate a single

technology. Because this study compared two technologies: the digital pen and paper system versus the conventional pen, items were modified to reflect two directions of preference. A score of one indicated a strong preference for the digital pen and paper system, while a score of seven indicated a strong preference for conventional pens. According to the null hypothesis of no preference, the expected score would be four. Figure 6 illustrates a typical item with the 7-point Likert scale.

Figure 6. Example of the questionnaire item



4.6.2. Instrument 2: Observer/ Interviewer:

The second instrument for data collection in this study was an observer who also acted as an interviewer. The observations and the interviews were conducted by a trained nurse with graduated training in health informatics and an interest in usability of information systems. Although observations and interviews by a single individual may be subject to bias in this case, the prior training and experience of the observer can lead to better access as an "insider" who may have greater insight. To help control the potential bias, the study included three strategies of data collection, which provided a degree of triangulation. Observations were performed in the unit everyday according to nurses' working schedule, focusing not only on the experimental task (Admission Database form

completion), but also on the general interaction of the nurses and the digital pen as they performed other tasks and duties.

The observation schedule followed the nurses' schedule, a typical example of which is shown in Figure 6. Nurse 3 works on April 16, 17 and 18 for day shift from 7am to 7pm; Nurse 9 works on April 17 and 18 for evening shift from 3pm to 11pm, and so on.

Figure 7. Observation schedule example

ID	04/12/04	04/13/04	04/14/04	04/15/04	04/16/04	04/17/04	04/18/04
1			07-19	07-15	07-15		
2	07-12					07-15	
3					07-19	07-19	07-19
4	07-15	07-15	07-15				
5	07-15	07-15		07-15	07-23	07-15	07-15
6			07-15	07-19	07-19		
7		07-19					
8		15-23	15-23	15-23		15-23	15-23
9						15-23	15-23
10		23-07	23-07	23-07	19-07	23-07	

Time	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Attend		X								X				X				X	

Observations were conducted at 7am, 3pm, 7pm and 11pm to coordinate observations and distribute digital pens (Figure 7). Additional visits to the unit were made at arbitrary intervals to assist with any technical problems, to ensure adherence to study group assignments and to perform additional observations. Each observation mean lasted about 30 minutes, ranging from 15 to 90 minutes, depending on observer convenience or technical requirements. Field notes were recorded at the time of each visit, and detailed transcription was completed within 24 to 48 hours. Over 110 hours of observations were

conducted during approximately 200 visits between April 14 and June 6, 2004 (including weekdays and weekends on all three shifts).

Interviews were held during the final week of digital pen and paper system use. The purpose of these interviews was to explore additional information not covered by the questionnaire. The semi-structured interviews included open-ended questions addressing the study aims as well as detailed questions exploring issues that arose during earlier observations. The original interview questions were modified in later interviews to explore issue that arose in the initial interviews. In some instances, additional prompting by the interviewer was used to further explore brief or vague subject responses. The semi-structured interview questions for both groups are listed in Appendix C.

4.6.3. Schedule Overview

The study was completed during an eight-week period. Observations were spread across the entire eight weeks. Interviews were held during a subject's final week of digital pen and paper system use to reduce any recall bias. Questionnaires were completed at the end of the entire study period for the comparison of digital and conventional pens. The timeline of the data collection is shown in Table 2.

Table 2. Timeline of data collection

	W1	W2	W3	W4	W5	W6	W7	W8
Observations	X	X	X	X	X	X	X	X
Interviews				X (G1)				X (G2)
Questionnaires								X (G1, G2)

4.7. Data Analysis

The questionnaire provided ordinal preference data on a scale from one to seven. The data was analyzed using the Wilcoxon test (equivalent to the Mann-Whitney test), which is used for non-parametric data to test the significance of the difference between the two samples. Two analyses were performed. First, data from all subjects were combined to test the null hypothesis of no preference for either device (hypothesis one). Second, the two groups were compared to one another to test whether the two groups expressed different preferences, which might be due to a time effect. All tests were performed using SPSS version 10.0.

The qualitative data included transcripts of observation field notes and transcripts of interviews with all nurses. Content analysis was used to analyze the qualitative data. Each transcript was read by the investigator, making note of themes and patterns. As additional transcripts were examined, similar themes were combined with attention to subjects' statements relating to usability. Selected transcripts were reexamined to confirm the final themes reported below in Results.

5. Results

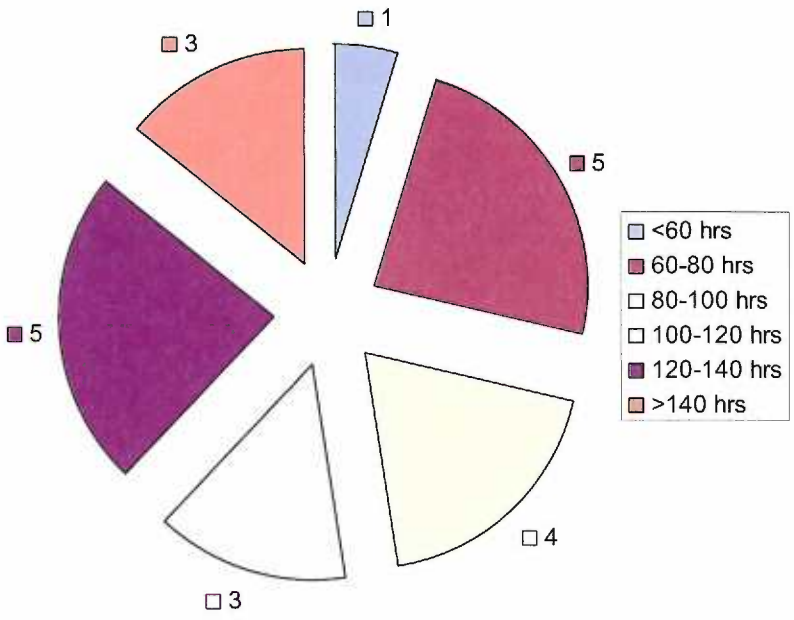
5.1. Subjects

Table 3 shows the distribution of nurse subjects across the three shifts in Groups 1 and 2. Most of nurse subjects work at least 0.7 FTE suggesting that they had ample opportunity to use the digital pen and paper system. Figure 8 shows the number of working hours of nurse subjects. All the nurses were able to access the digital pen and paper system for more than 60 hours.

Table 3 The distribution of nurse subjects across three shifts

	Group 1	Group 2	Total
N	10	11	21
Shift – Day shift	7	8	15
Evening shift	2	2	4
Night shift	1	1	2

Figure 8 The number of working hours of nurse subjects



5.2. Quantitative Results

All twenty-one nurses completed the questionnaire and there were no missing items.

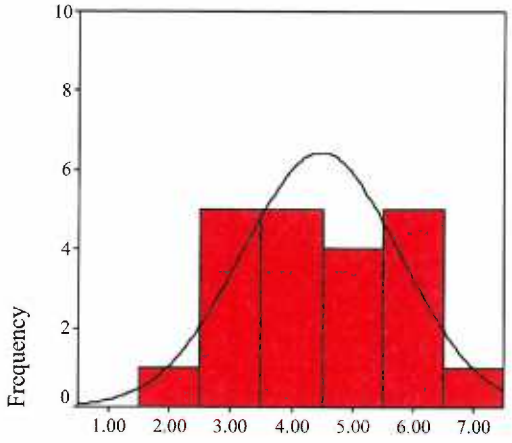
5.2.1. Raw Preference Data

Basic descriptive statistics and histograms of data for each item in the questionnaire are provided in Appendix D. For most items, inspection of these histograms reveals a preference for conventional pens. There were two exceptions. On items five and nineteen, both of which ask the subjects which pen is "a good idea", the subjects expressed a preference for the digital pen.

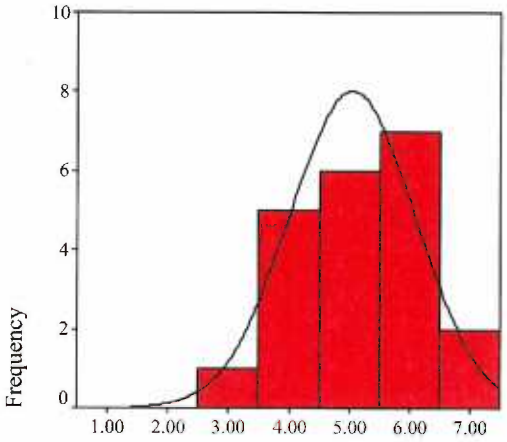
Questionnaires items were clustered according to the factors (usefulness, ease of use, compatibility, and attitude) by calculating the within-subject means of the items associated with each factor. Combined data for these clusters are illustrated in Figure 9. For each histogram, a score of four indicates no preference; a score of seven indicates a preference for the conventional pen; and a score of one indicates a preference for the digital pen. Inspection of the usefulness scale reveals that the nurses expressed a slight preference for conventional pens. A stronger preference for conventional pens is suggested on the ease of use scale. Inspection of the compatibility scale reveals that about half of the nurses expressed no preference while the other half preferred conventional pens. By contrast, inspection of the attitude scale suggested a slight preference for digital pens rather than conventional pens.

Figure 9. Histograms of Composite Scales for Usefulness, Ease of use, Compatibility, and Attitude

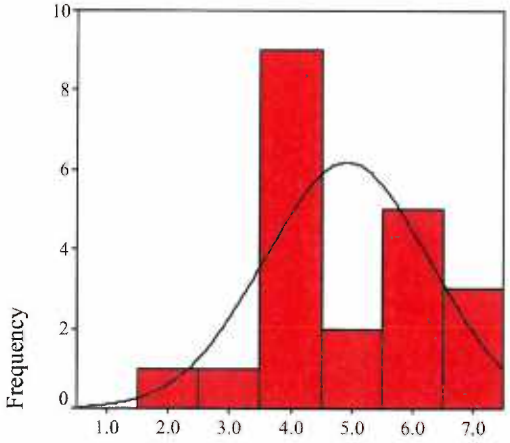
9a. Usefulness
N = 21
Median = 4.17
Mean = 4.48
SD = 1.30



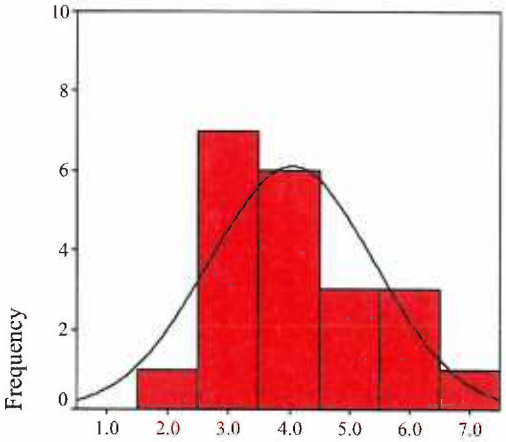
9b. Ease of use
N=21
Median = 5
Mean = 5.05
SD = 1.04



9c. Compatibility
N = 21
Median = 4.33
Mean = 4.90
SD = 1.35



9d. Attitude
N = 21
Median = 3.75
Mean = 4.00
SD = 1.37

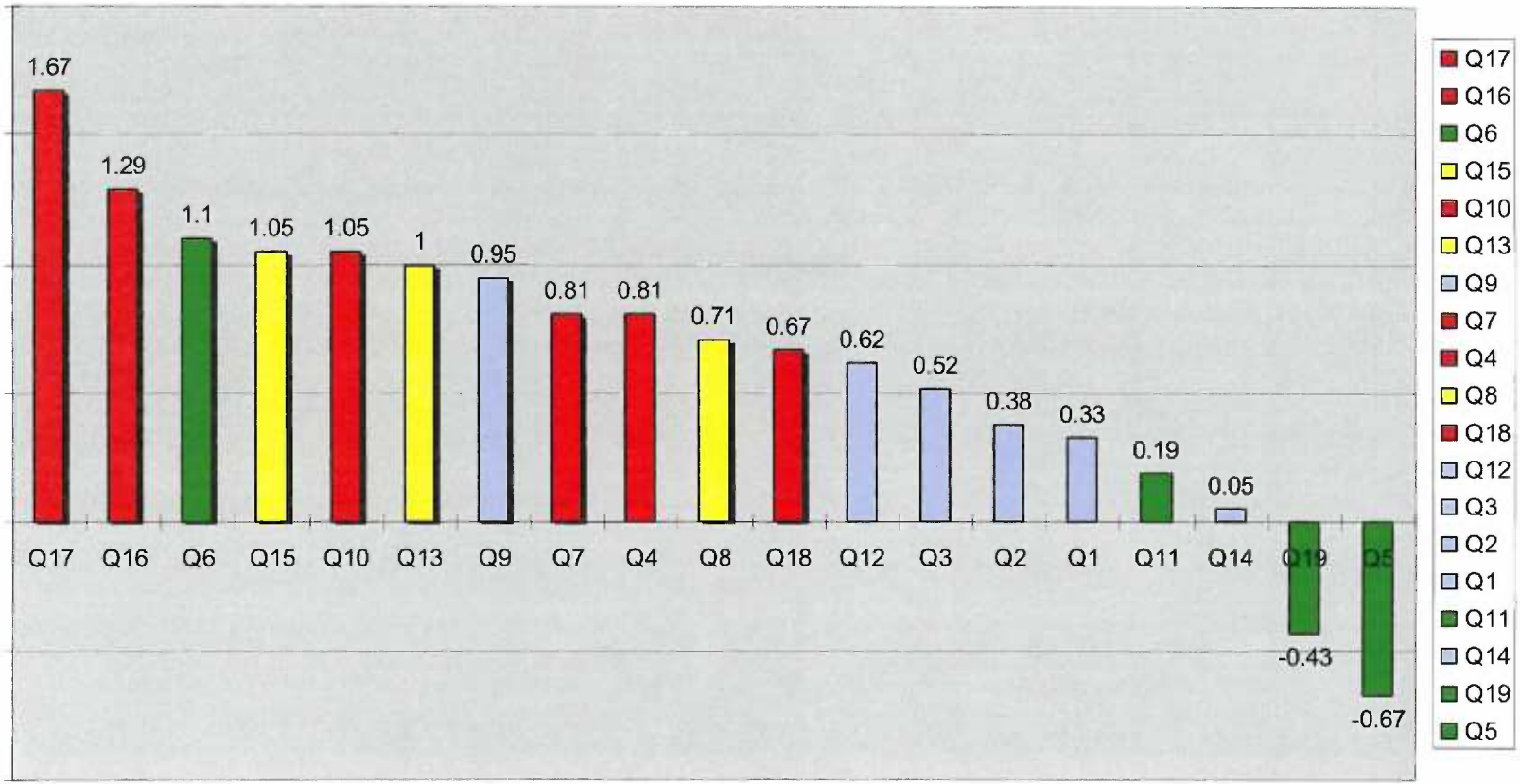


To compare the relative strength of these preferences, the data for the 19 questionnaire items are displayed in Figure 10. The mean score for each item was calculated and transformed by subtracting four so that a value of zero in Figure 10 indicates no preference. The items were then sorted by the relative strength of preference. In Figure 10, an upward deflection indicates a preference for conventional pens and downward deflection indicates a preference for digital pens. For example, the strongest preference for conventional pens is seen with item seventeen (at far left), which concerns ease of use, while a moderate preference for digital pens is seen with item five (at far right), which concerns whether the digital pen is a good idea. As the coding of the bars according to the scales indicates (see caption of Figure 10 for codes), items concerned with "ease of use" appear toward the left suggesting stronger preference on that scale for conventional pens. In contrast, items concerned with "attitude" tend to appear toward the right consistent with the preference for digital pens.

These results suggest a preference for conventional pens in terms of usefulness, ease of use and task compatibility, but a positive attitude toward the idea of digital pens. To examine these apparent preferences more fully, statistical analysis was performed.

Figure 10. Relative strength of preference.

Blue: Usefulness
Yellow: compatibility
Red: Ease of use
Green Attitude



5.2.2. Hypothesis 1: No Preference for Either Pen

The Wilcoxon test was used to examine the preferences apparent in the raw data described above, with the null hypothesis being no preference for either pen. A score of four on each item and each scale indicates no preference for either pen. If the null hypothesis is true, the observed score will not be significantly different from score four.

Table 4 shows the Wilcoxon test results for the nineteen items in the questionnaire. These results indicate a significant preference for conventional pens (#6, #8, #9, #10, #13, #15, #16, #17 and #18). Most of these items belong to the scales for "ease of use" and "compatibility". Furthermore, the result for a composite of all nineteen items combined showed a statistically significant preference for conventional pens.

Table 4. Wilcoxon test results for questionnaire items

Item description	z scores*	p values
Q1. productivity	-1.102 a	.270
Q2. job performance	-1.452 a	.147
Q3. usefulness	-1.493 a	.135
Q4. easier to become skillful	-1.875 a	.061
Q5. good idea	-1.434 b	.151
Q6. unpleasant	-3.007 a	.003
Q7. easier to do what I want	-2.264 a	.024
Q8. fits into work style	-1.987 a	.047
Q9. accomplish tasks quickly	-2.586 a	.010
Q10. flexible	-3.068 a	.002
Q11. foolish idea	-0.850 a	.395
Q12. makes job easier	-1.630 a	.103
Q13. setup compatible with my work	-2.623 a	.009
Q14. enhance my effectiveness	-0.241 a	.809
Q15. fits better with my work	-2.645 a	.008
Q16. easier to learn	-3.002 a	.003
Q17. easier to use	-3.581 a	.000
Q18. easier to understand	-2.122 a	.034
Q19. like the idea	-0.816 b	.414
Composite Q1-Q19	-2.086 a	.037

* a: trend toward conventional pens; b: trend toward digital pens

Table 5 shows the Wilcoxon test results for the four scales: usefulness, ease of use, compatibility, and attitude. Consistent with the individual item data presented in Table 4, a statistically significant preference was found for the "ease of use" and "compatibility" scales. Although inspection of the raw data suggested a preference for digital pens on the "attitude" scale, this was not found to be statistically significant using the Wilcoxon test.

Table 5. Wilcoxon test results for the four scales

Scale	z scores*	P values
Usefulness	-1.410a	.159
Ease of use	-3.323a	.001
Compatibility	-2.661a	.008
Attitude	-2.262b	.793

* a: trend toward conventional pens; b: trend toward digital pens

5.2.3. Hypothesis 2: No Time Effect Between Two Groups

Hypothesis two was concerned with whether the perceptions of subjects with early exposure to the intervention would differ from the perceptions of subjects with later exposure. Group 1 and Group 2 data were compared using the Wilcoxon test for all 19 test items, a composite of the 19 items and the four scales, with alpha set at 0.05. In none of these cases was a statistically significant difference found between the two groups (Table 6). These results suggest that the time difference in exposure to the intervention (digital pen and paper system) is due to the crossover design did not influence the results.

Table 6. Results of hypothesis 2

Item/Scale	z scores	p values
Q1. productivity	-.804	.422
Q2. job performance	-.787	.431
Q3. useful	-.107	.915
Q4. easier to become skillful	-.433	.665
Q5. good idea	-1.570	.116
Q6. unpleasant	-.951	.341
Q7. easier to get to do	-.401	.688
Q8. fit in work style	-.479	.632
Q9. accomplish tasks quickly	-.658	.510
Q10. flexible to interact with	-.481	.631
Q11. foolish idea	-.927	.354
Q12. easier to do job	-.074	.941
Q13. compatible to work	-1.701	.089
Q14. enhance effectiveness	-.313	.754
Q15. fit better in work	-.649	.517
Q16. easy to learn	-.417	.677
Q17. easy to use	-1.508	.132
Q18. easy to understand	-1.049	.294
Q19. like the idea	-1.355	.175
Composite of Q1-Q19	-.353	.724
Usefulness	-.300	.548
Ease of use	-.888	.375
Compatibility	-.953	.340
Attitude	-.388	.698

5.3. Qualitative Results

Qualitative data collected in this study included field notes of observations by the investigator and transcripts of interviews with twenty-one nurses. Field notes taken during approximately 200 separate visits to the nursing unit were transcribed within 48 hours of the visit. Interviews were conducted as soon as possible after at least three weeks of digital pen use.

5.3.1. Observations – Field Notes

Initial Excitement

In the beginning, most of the nurses appeared to be excited about using the digital pens. For example, some nurses who were assigned to Group 2 were somewhat disappointed they were not assigned to Group 1 since they were looking forward to trying the digital pen. The digital pen generated conversation and curiosity among the nurses on the unit (both those involved in the study and those not involved). Most of the nurses had a positive attitude about using the new technology. However, after only a few days, the nurses began to discuss some disadvantages, for example: "the size is too big", "the cap doesn't fit", etc.

Adopting the Digital Pen for Routine Use

Nurses began to handle the digital pen like a conventional pen. For example, during conversation they would remove and replace the cap unconsciously as they did with the conventional pen. Similarly, nurses used the digital pen as a pointer, pointing to the white board, the computer screen or other objects, again just as they would use a conventional pen. The digital pen appeared to have been assimilated by the nurses as a routine tool.

After the Honeymoon Period

After an initial positive response in the first few days, nurses began to use conventional pens for most tasks, reverting to the digital pen only for completion of the Admission Database form. Some nurses explained that they simply reach for the most accessible pen. Conventional pens were easily available everywhere on the unit: on the

desks, in their pockets, etc., while each nurse had just one digital pen. Without thinking, they would reach for the first pen they could find – often as not this would be a conventional pen. Some nurses would only use the digital pen for the study task, using a conventional pen for everything else.

It's the Pen, Not the Form

Nurses appeared to focus on using the digital form and frequently reported to the investigator the number of forms completed, appearing apologetic about the small number of patients admitted. They did not appear to recognize that the study was concerned with their interaction with the digital pen and the need to incorporate it into general use, even though this had been included in their original instructions. Nurses were again encouraged to adopt the digital pen for routine use, but nurses varied in the degree to which they followed this recommendation. Some carried only the digital pen and used it regularly, while others avoided the use of the digital pen except when completing the Admission Database form.

Making Adjustments

About one week later, some preferences began to appear. Several nurses used conventional pens at all time except when completing the Admission Database form. One of the nurses acknowledged this, stating she used her digital pen only when she had to. Otherwise, she would not use it. The reason: "it's bulky".

In contrast, other nurses adopted the new device into routine use, using it as they would a regular pen. For most, the frequency depended upon the situation: if they were busy and had no time to think about which pen to use, they would just grab the most accessible pen. Those who used the digital pen adjusted their behavior to do so. For

example, because the digital pen cap did not fit on the back of the pen, some nurses put the cap in their pocket instead, leaving it off until they finished their charting. This meant setting down the pen without the cap in between charts. Even though this resulted in a shorter battery life, it made using the pen less cumbersome, because of the poorly fitting cap. Another adjustment involved placing the pen in their pocket. While nurses usually kept a conventional pen in their front shirt pocket for easy access, the bulk and weight of the digital pen made this impractical. Their work requires frequent bending, stooping, and leaning, so the pen would easily fall out of a shirt pocket and be damaged. As a result, nurses adjusted their behavior, placing the digital pen in their back pocket, though this is less convenient for them to access (Figure 11).

Figure 11. Demonstration of the digital pen storage by the nurses.

Some nurses were very interested in using the digital pen and understanding its usefulness, so they adjusted their behavior even further. When carrying the digital pen, these nurses took care not to have a conventional pen with them. They said that they "quit" conventional pens to force themselves to use the digital pens at all time.

5.3.2. Interviews

Interview results were organized based on the four main components of Bennett's usability framework: tool, user, task and environment. Thus the tool was the digital pen; the users were the Labor and Delivery nurses; the task was completion of the Admission Database form with the associated workflow; the environment was the Labor and Delivery unit. The quotes that follow are accurate but not verbatim as they are based on interviewer's notes and not exact transcripts or recordings.

5.3.2.1. Tool – the Digital Pen and Paper System:

Nurses in this study made both positive and negative comments about the device in their interviews. Most of the positive comments were concerned with its novelty, while most of the negative comments were concerned with its physical characteristics.

☹ *"<u>It is bulky!</u>"*

The size of digital pen is about three times that of the conventional pen. Most of the nurses thought it was too big, only a few found its size acceptable. Furthermore, due to its size, in certain orientation, nurses could not see the point of the pen, making it difficult to place the pen precisely when marking a check in a checkbox. Figure 12 shows the comparative size of the digital pen and a conventional pen used by the nurses.

- ✧ *"I would expect it to be smaller"*

- ✧ *"It's bulky!"*
- ✧ *"I like skinny, tiny pen better"*
- ✧ *"I can't see the point [of the pen]"*

There were some exceptions. Some nurse found the physical characteristic to be an advantage: *"It looks special, so it is hard to lose. Everyone would know this is not their pen. And it is big, so it's easy to see where it is".*

Figure 12. Relative Size of the digital pen and conventional pens

☹ *"<u>The cap doesn't fit!</u>"*

All of the nurses had problems with the cap, which does not fit on the back of the digital pen. This was a big problem for them because they had to worry about losing the caps.

- ✧ *"I hate the cap!"*
- ✧ *"The cap doesn't fit, and it is really important. Last time I did some*

charting there [nursing station], and suddenly I need to go to see my patient, but I can't find my cap. I try to fit it on my pen, but it just dropped somewhere, and I can't find it. At the time I was at the bedside, I was thinking about 'oh, I got to find my cap, or Po-Yin will kill me'"

☹ *It falls out of your pocket*

Some nurses thought the weight of digital pen was too heavy, but some did not. They expressed concern that the pen could easily fall out of their pockets. Because they are so mobile, it is necessary to keep important tools handy in their pockets. If they cannot store the pen securely, it is more difficult to use.

- ✧ *"I think the weight doesn't bother me as long as it doesn't fall in the toilet"*

☹ "*I don't like that it vibrates all the time*"

☺ "*I like the jolt, it was fun*"

The digital pen is designed to vibrate whenever it is not used on digital paper. This is meant to serve as a useful alerting function. Some nurses did not like this vibration because it distracted them. Others liked it, because they thought it was fun. Still others did not care. One nurse explained this feature was kind of fun because she used the pen infrequently, but predicted it would bother her if she had to use it all the time.

- ✧ *"It is a little distracting"*

☺ *"It writes well", "Comfortable to hold"*

All of the nurses thought that the digital pen writes smoothly. And some of them found the ergonomic shape of digital pen to be comfortable to hold.

- ✧ *"The ink flows very well"*

☹ *"I prefer black ink"*

In the beginning, only blue ink was offered for digital pens. Some nurses thought the ink color might be a problem because of copying issues, but others did not. Black ink cartridges were supplied in the later half of the study and no further concerns were raised on this issue.

😐 *Computer connection*

Most of the nurses found the connection of the digital pen to the computer to be very easy to operate, including the connection to the software. However, the system was configured for a very specific workflow that sometimes interfered with viewing data, which the nurses had just been transferred.

- ✧ *"It is not like you can see it right away. You still have to open the files. It would be better if there are only one or two clicks."*

5.3.2.2. User -- Nurses' Perception of Usability:

In general, nurses had positive comments about the idea of the pen and its potential advantages, but they noted disadvantages when using the digital pen for an actual task.

☺ *"I like the idea"*

More than half of the nurses thought that the idea of the digital pen is good. They recognized the potential advantages of better access to patient data and less potential for missing elements of medical records, such as misplaced or misfiled forms.

- ✧ *"The concept is creative"*
- ✧ *"The system is cool, the engineering is cool"*

😐 *Accessibility and Data Integrity*

In addition to recognizing the potential benefits of greater data accessibility and integrity, some commented that accessibility and integrity of patient data could also be reduced, such as with system failure or when an individual fails to perform the extra step of data transfers.

- ✧ *"If other nurses use the pen, I can access the data by computer … no need to ask them to fax it."*
- ✧ *"It could decrease the missing data…And we don't need to do computer charting.*
- ✧ *"We take…responsibility to remember to download the data, too. Otherwise, the data would be gone. I still like the conventional pen better"*

😐 *Save paper?!*

Some nurses thought using an EHR is a good way to save paper, but since using the digital pen and paper system still uses paper, they think this system makes no difference in paper use. Other nurses believed it could save paper because they don't need to transmit patients' record by copying or faxing.

- ✧ *"I still can't see any benefit of it… We still use the same paper in the same steps…. If we want to have electronic medical record, why can't we just use a computer to do the data entry, so it saves paper"*
- ✧ *"It could save the trees"*

☺ *"It is easy!"*

All the nurses thought the digital pen is easy to use and takes only a little time to learn how to use it. Nurses who had no confidence in using computers found it easy to

use the digital pen.

- ✧ *"Most important thing, I like that we don't need to switch to other pens, it can be used as a regular pen."*
- ✧ *"It's easy, because you don't need to remember any code, or sequence, or procedures to use."*

😐 *"No benefits in nursing practice"*

Although they see the potential advantages for others, such as researchers or other clinicians, most of the nurses did not notice any direct benefit of the system for performing nursing documentation. Nurses hoped for direct benefits to their work practice, such as improved workflow, savings in time and effort of documentation, but the system changed none of these.

- ✧ *"It doesn't improve my handwriting"*
- ✧ *"I still do the same things … I don't use the data. I think it would be good for researchers or other clinicians who want to see the data or use the data. It probably saves their time and has benefits for them."*

☺ *"It was fun"*

Most of the nurses reported that they enjoyed participating in the study. They like to try new things. They like the novelty, they like seeing their own handwriting on the computer screen, and they like the effect of the digital pen on their interactions with others.

- ✧ *"I had another student with me…. I let her fill out all the forms, but if it were the admission form, I would do it. I think I enjoy using it."*
- ✧ *"Getting conversation with other people. You know, you have the pen, and*

people will ask, and you can have a good conversation with them."

☹ *"I'm afraid to break it or lose it"*

Most nurses were concerned about losing or breaking the digital pen, because of its cost and fragility.

- ✧ *"I don't want to lose or break your pen even though you won't ask me to pay for it."*
- ✧ *"I don't want to worry about it all the time"*

5.3.2.3. Task – Changed in Workflow

In the interviews, nurses reported that using the digital pen and paper system caused a change in their workflow: they were required to go to the nursing station, connect the digital pen, interact with the software, and save the data. Some nurses objected to these extra steps, while other nurses did not mind because it was usually simple and quick, and they could work these steps in at their convenience. Furthermore, some suggested that it would be better if all the forms were digital forms so they would not need to remember which one is the digital form.

☹ *"It takes an extra step to download the data!"*

☺ *"It is easy and quick. I don't think it's a problem"*

- ✧ *"...when I was busy at the bedside, I filled out the regular admission form and suddenly remembered that I have to use the special form"*
- ✧ *"...it is too far to come back to the station just to download it"*

5.3.2.4. Environment – Support and Configuration

Most nurses observed that the work environment did not fully support the use of the digital pen and paper system. To a great extent this was due to the fact that the system was only a partial implementation, isolating this task and its tools from all their other work.

☹ *We don't have multiple accesses*

Environment support is very important for the nurses using the digital pen and paper system. Because the study only used one form for the task, one pen for each nurse and one dock for downloading data, it is more difficult for the nurses to access to the system. Therefore, lots of complaints were made from the insufficient environmental supports.

Forms:

- ✧ *"If it is used for every form, that's fine. But it is for only one form... it is inconvenient.... When I am busy, it's like out of your way."*
- ✧ *"It is just the location of the forms, it is not easy to access"*

Docks:

- ✧ *"...more docks to download the data would be good..."*
- ✧ *"If we could have the computer at the bedside..."*

Pens:

- ✧ *"The most important thing I worry about is bringing it home. I don't want to drive 45 minutes... just for the stupid pen."*
- ✧ *"...doing some messy work [with body fluids]... I can't throw your pen away, maybe I can clean it, but I'm not sure if I can."*

- ✧ *"I will use the first pen I grab…so it is about half the time."*
- ✧ *"If I left the pen in the bedside…then I need to come back to the bedside to get the pen."*

5.3.2.5. Which would you choose?

At the end of the interview nurses were asked if they had their choice of documentation devices including computer charting, PDA, tablet PC, digital pen, or conventional pen, and which they would prefer to use and why.

More than half the nurses preferred to use a pen, any pen, over keyboard entry, because they believe pens are easier to use. They would be more likely to use the digital pen if it could be modified to address the physical issues mentioned above. Only four nurses chose computer charting giving the reason that their typing is faster than writing. All the nurses seemed to choose the device that was most comfortable and/or most convenient, also taking into account the importance of data integrity and accessibility.

☺ *"I like pens. I like to write"*

☹ *"My typing is faster than writing"*

Pen preferred:

- ✧ *"It would be wonderful if we were able to use it for all the charting. [Why?] We could get the data immediately and wouldn't lose the form …it would be accepted by more people …though it takes extra steps … I think it is worth it."*
- ✧ *"I had experience using computer charting before, and I don't think it is easier. There were only 4 or 5 computers in the ward, and you would need to wait for the computers. Besides…you need to type and click. It is time*

consuming. I would rather use the digital pen and take more time with my patients"

- ✧ *"I like the pen better [than PDA?] The screen is too small. It is hard to see."*
- ✧ *"I don't like computer charting because there are too many different screens."*
- ✧ *"I would choose the digital pen. Because it is easier to use, and learn. And we still use paper. I'm faster at writing than typing ... I think it would be a bridge between paper and computers. It is just more similar to what we are doing now."*
- ✧ *"I like the idea of the digital pen [compared to computer charting?] I don't like computer charting because ... it's like there is only one standard ... you have only certain things to choose ... using paper, I can decide which to emphasize, and describe it"*
- ✧ *"I would probably choose tablet PC or digital pen. [Why?] I don't like computer charting at the bedside; because you have to remain in front of the computer, and can't move around or face the patient ... I can also use a digital pen doing my charting on my clip board, and chart anywhere."*

Computer charting preferred:

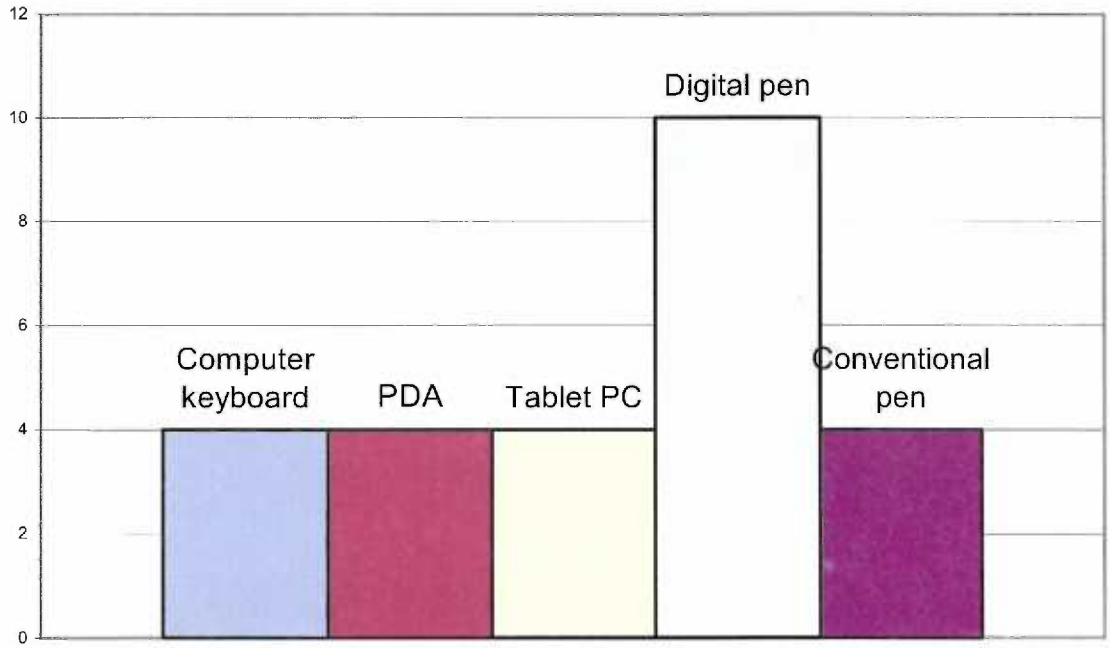
- ✧ *"I'm comfortable with the keyboard"*
- ✧ *"My typing is faster than writing"*

Nurses' preferences for documentation devices are summarized in Figure 13. Each nurse indicated which devices were preferred for nursing documentation, allowing

her to indicate more than one device when they were equally preferable. Two nurses had no preference, and another two nurses early in the study were not asked this question. As the figure shows, the digital pen received the most votes. For ten of seventeen nurses, the digital pen was one of their preferred devices for documentation.

It is somewhat surprising that so many nurses would express a preference for the digital pen after objecting to its physical characteristics. Three possible explanations for this result are: first, though they did not like digital pens in the current design, they foresee the potential benefits of the device. Second, according to Nelson's usability perspectives, users can only guess what they will do in the future – they may not be correct (Nelson's perspective will be discussed further in the Discussion section). Third, this may represent an experimenter effect where the subjects did not wish to displease or disappoint the researcher. Which explanation is correct is unknown.

Figure 13. Nurses' preferences for documentation devices.



6. Summary of Findings

In summary, this study found that nurses had a positive attitude toward the system and could foresee its potential benefits. But they found that in its current design, the system had poor usability and interfered with nurses' work practices.

7. Discussion:

7.1. Lessons Learned

7.1.1. Nursing work is different

Two important features of nursing work with implication for the digital pen and paper system are the nurses' focus of attention and mobility. In this study, the nurses found that the digital pen and paper system could be a significant distraction. They had to keep track of the poorly fitting cap, they had to make adjustment for the weight and bulk of the digital pen, and they had to worry about losing or damaging it. These distractions diverted the nurses' attention from the more important and urgent demands of patient care.

Another fundamental aspect of nursing work is its mobility. During the fieldwork phase of the study, nurses were observed performing documentation at the patient's door, at the bedside, at the nursing station, in the conference room – almost anywhere. This mobility was well supported by the small, portable digital pen. Some nurses reported that this portability also allowed them to interact with their patients as they performed documentation. On the other hand, the single dock for the digital pen connection tended to interfere with the nurses' requirement for mobility. Portability of the documentation device is essential because recording clinical data immediately at an event contributes to accuracy of the record (43). Mobile documentation also reduces the delay that occurs

with scanning technology or double data entry (10). Similar findings were reported in a study of mobile digital assistants (like a PDA) (44). Because mobile documentation increases the accuracy and integrity of the clinical record, it may be more acceptable to clinicians (45).

7.1.2. Familiar technology is more acceptable

The nurses' attitudes toward the digital pen were positive even though they did not find the digital pen usable with its current design. Some of the nurses mentioned that they could use a digital pen just like a conventional pen. Previous studies reported that people are more likely to accept a new technology when they have confidence based on using similar tools. For example, nurses who have used computers at home and have basic knowledge and skills with computers have more confidence and would be more willing to use a computer for charting (45-48). Second, training increases users' acceptance of technology, since training increases familiarity (49, 50). Consistence with these studies: although the digital pen and paper system was not found usable in its current design, the nurses showed a positive attitude because they felt digital pens could be used just like conventional pens. Furthermore, learning time should be reduced with a device as familiar as a pen.

7.1.3. Positive Attitude

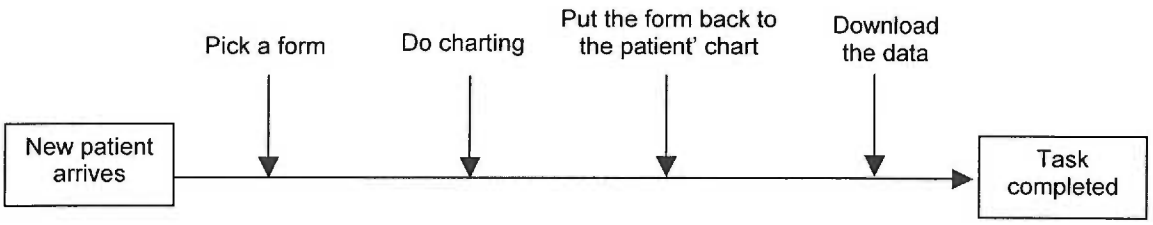
Nurses demonstrated a notably positive attitude toward this new technology in spite of its shortcomings. Although they ultimately rejected this device, this was due to specific problems with usability, not to the idea of the digital pen itself. They recognized the potential value and looked forward to the benefits of an electronic nursing record. These

nurses could foresee the advantages of better access to clinical data, improved data integrity, and enhanced collaboration and communication among clinicians. The nurses could also foresee the potential benefits for research and quality improvement.

7.1.4. Change in Workflow

Prior to the study, an outsider is likely to have an idealized view of how the digital pen and paper system might fit into nurses' workflow in performing the documentation task. This workflow is illustrated in Figure 4 and described in detail in Section 4.4. During the study, it was observed that this description is largely accurate for regular conventional pen usage. At times a nurse might simultaneously join a patient and grab a form as she walked past the desk. At times other tasks might be performed at the same time, but in general the steps of this task were completed in this sequence (except for the download step, which is only relevant for the digital pen and paper system).

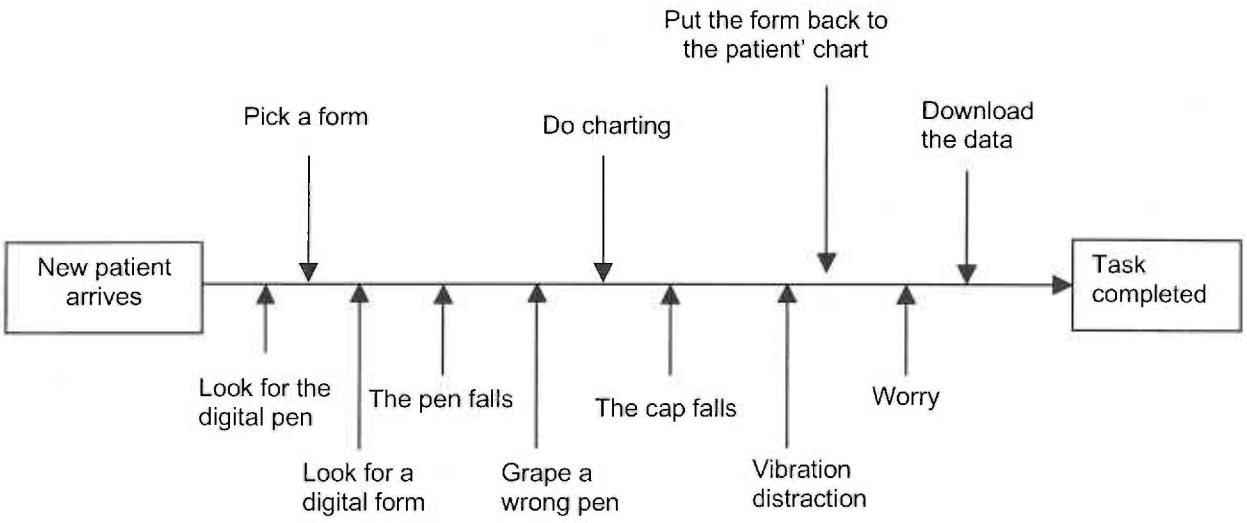
Figure 5. (repeated from page 22) Idealized workflow



However, it was observed that the workflow actually changed with the digital pen and paper system. In a typical scenario (with the digital pen and paper system), when a patient arrived, a nurse needed first to locate her digital pen since she had only one available. Then she had to find the digital Admission Database form, kept only at the nursing station. Bending over to perform another task, the digital pen might fall from her

front pocket. Picking up the digital pen, she might relocate it to her back pocket where it is safer. Finally, she arrives at the bedside, reaches to her front pocket as she normally would, but finds only a conventional pen. She retrieves the digital pen, opens the cap, and puts it on the back of the digital pen. Starting to write, the cap promptly falls off again. Retrieving the cap, she sets it on the counter. While charting, the digital pen begins to buzz and vibrate (whenever it is not located properly over the digital paper) distracting her from the conversation with her patient. Finally, she completes the form, and begins other nursing care. Suddenly, she remembers the cap, which was left on the counter, but has now disappeared. She is afraid she has lost it, but finds it under the bed. When she is done, a new patient has arrived. But before she can begin this new patient's admission, she must return to the nursing station to download data because the system can only contain one record at a time. This worst-case scenario, a composite of events that were observed or reported, resulting in a change in workflow illustrated in Figure 14.

Figure 14. Possible Revised Workflow



7.1.5. Unresolved System Issues

At least three additional issues will need to be addressed for successful implementation of this technology. First, data integrity will need to be ensured when information is transferred from the digital pen to the computer. All of the benefits of the system depend critically on absolute accuracy of the data entered. This study focused only on usability and did not address other issues. Before a device such as this can be implemented, other studies will be required to demonstrate the accuracy and completeness of the data after it is transferred into the computer.

A second issue that will need to be addressed is the handwriting recognition function. In the present study, the recognition software performed well in recognizing numbers, but was less effective at recognizing letters. Although accurate transfer of hand written forms would allow electronic access to the data by other clinicians without effective handwriting recognition, the benefits of a fully electronic nursing record cannot be realized.

Third, down time is a critical problem in every information system meant for clinical use. During this study, there were three instances where the software abruptly froze during data transfer. In each case, nursing personnel were reluctant to attempt to remedy the problem, leaving it for the more technically minded researcher to reboot the computer. This meant the system was inoperative for as much as 24 hours. Fortunately, no data appeared to have been lost. However, stability of the digital pen and paper system, appropriate back up mechanisms, and adequate technical support would be needed before the system can be adopted for clinical use.

7.2. Bennett's Model

The findings of this study are consistent with Bennett's Model of usability (18). According to the Bennett model, usability incorporates user, tool, task, and environment, and each of these interact with the others. Any change in one will influence the others (Figure 15). In the present study, the researcher provided only a new tool, but as a result of this change, effects were observed in the other components of usability. The users (the nurses) changed in their interaction with the tool (the digital): they carried it in a different pocket (compromising accessibility in favor of safety) and adjusted the pen position to see the point while they wrote. The task, completion of the Admission Database form, was changed as well: they needed to go out of their way to locate the form, which interrupted their workflow to download the data. The environment, the Labor and Delivery unit, was not changed yet, but nurses agreed changes would need to be made in order for the system to be a success. Therefore, to improve usability, designers or engineers must take into account not only the device they are designing, but also the other components of the Bennett model: the user, the task(s) and the environment (Figure 15), all of which contribute to usability (Figure 16). Ammenwerth has proposed an analogous model (the Fit between Individuals, Task, and Technology, FITT) by combining the Technology Adoption Model (TAM) of Davis, the Information Technology Adoption Model (ITAM) of Dixon, and the Task-Technology-Fit Model (TTF) of Goodhue and illustrated the model using a case study (51).

Figure 15. Benett's model of usability

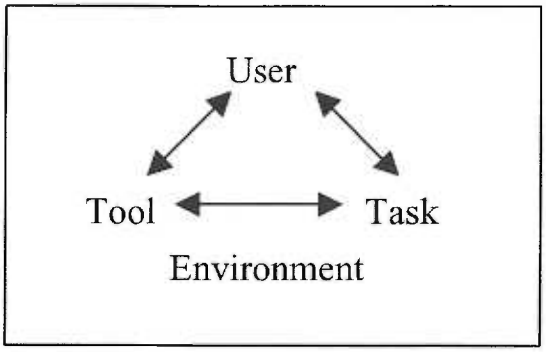
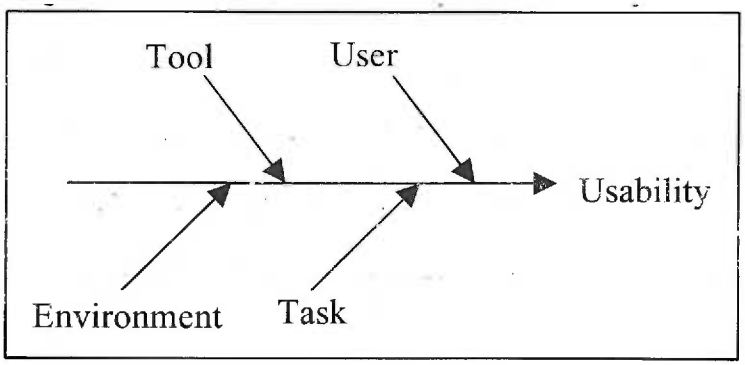


Figure 16. Fishbone concept of usability



7.3. Conclusions about Methodology

The Bennett model of usability described above served as the basis for the methodology of this study. Using this model during field work, the investigator was able to focus observations not just on a single aspect of usability, such as the user-tool relationship, but on the entire set of relationships among user, task, tool and environment. Similarly, the design of the interviews and the choice of the questionnaire were guided by this comprehensive model. The results of each approach were consistent with one another

and thus the findings of the study are more likely to be valid because of this triangulation effect (52).

7.3.1. Usability testing important to learn users needs

Shackel defines *useful* and *usable* as follow: "useful means advantageous, profitable, fit for some desirable end, or having power to satisfy human wants, while usable means able to be used, applicable to a purpose" (15). The results of the present study are a good example of this distinction. While the nurses in general had a positive attitude toward the digital pen and paper system (they perceived that it would be useful), they could not accept it in its current design (they found that it was not usable). This is why usability testing is so important: without it, it is not possible to identify and address usability problems of the digital pen and paper system or any new technology.

7.3.1.1. Complementary Strategies

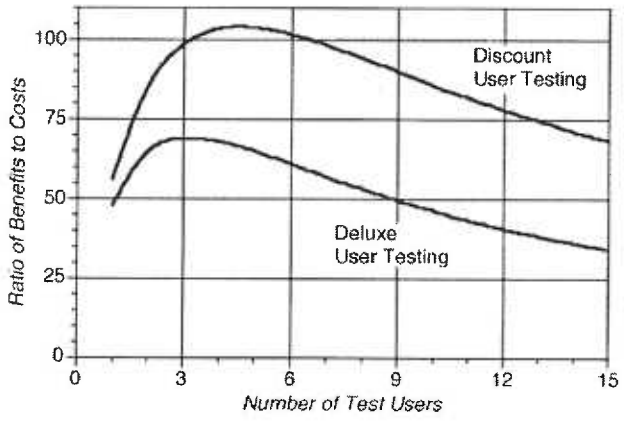
Three strategies were used to conduct usability testing in this study: observation, interview, and questionnaire. This multi-method approach was beneficial not only because of enhanced validity, but also because each of these different methods of obtaining data provided additional insight that might not have been obtained through the other methods. For example, in the interviews, nurses provided valuable perspectives that helped to define the usability problems of the system from actual use in their work. However, observations provided complementary information which did not arise in the interviews. This is consistent with Nielson's argument for usability testing: users can only guess what they will do, which may not be what they actually do (19).

There are several examples of this phenomenon in the present study. First, the problem of the poorly fitting cap was observed during fieldwork, but not mentioned by nurses during the interviews. Observations can thus be a remedy for recall bias. Second, behaviors such as removing and replacing the cap could be noticed by an external observer even when the subject is not aware of this behavior. Thus, observation can also provide information about unconscious interaction with the tool. Third, although most nurses expressed a positive attitude, some nurses appeared avoid the digital pen except for the experimental task. Observations such as this contradiction between what users said and what they did, made it possible to design more appropriate interviews, which explored were explored in greater depth.

7.3.1.2. Discount Usability Engineering

In the present study, most of the information that was uncovered through interviews was obtained from the first five or six nurses. Most of the interviews conducted after these first five or six, confirmed what had already been learned. Similarly, in this study, most of what was learned through observation was seen in the first two weeks. This is analogous to what has been reported with Discount Usability Engineering, where most of the important usability problems are discovered through examination by three to five experts (Figure 16. (19)). As Nielson has reported, this allows for faster and more efficient determination of usability problems with a product. In future usability studies of the digital pen and paper system or other devices, it may save valuable time of both the researcher and the nurses to use such an approach with fewer subjects or a short period of observation.

Figure 17. Sample Size in Discount Usability Engineering (53)



7.3.1.3. Limitation

This study has several important limitations. First, it is not known whether the results of this study can be generalized. The nurses who participated in this study were a convenience sample of volunteers, and may differ in terms of their curiosity, acceptance of new technologies, or other factors. The study involved a single task, on a single nursing unit, in a single teaching hospital. Whether the results would apply to other tasks, on other nursing units, in other hospitals, is unknown.

Second, there are potential limits to internal validity as well. The study was designed and conducted, and all observations and analyses were performed by a single individual. Although strategies to address potential bias, such triangulation of data collection and adoption of a preexisting, validated questionnaire, were employed, it remains possible that some degree of observer bias could be present. To date, no similar studies have been published to allow comparison of the results. Furthermore, this study examined only a partial implementation, and it is unknown how the result might differ if the digital pen and paper system were fully implemented.

7.4. Implications for Research, Development, and Implementation

7.4.1. For Researchers

There are two main challenges that must be addressed regarding this system: verifying the accuracy and integrity of the data, and demonstrating real benefits for clinicians, in particular for nurses. As stated in the Introduction, while nursing information systems help nurses to organize their work, manage nursing care plans, track diagnoses and outcomes, and support decision-making, all of these functions depend critically on absolute accuracy and integrity of the data in the electronic health record. Data accuracy and integrity were not examined in the study, but it is essential that they be studied if nurses are to accept the digital paper and paper system. No matter what benefits are expected from the system, it cannot truly help patients if they contain inaccurate data.

The second challenge that must be addressed is to demonstrate real benefits to nurses. Users are more likely to accept a new technology when the benefits they receive are greater than the effort they must expend (54). This is most apparent for users who benefit from the system without any effort on their part. Though nurses in this study could foresee the potential of the digital pen and paper system, the true utility and cost of using it remains unknown. For example, how can the database built by the system be used? How much time will or will not be saved? What are the well-defined benefits for nurses, other clinicians, or patients? Answering these questions can not only expand the degree to which the system is utilized, but also increase the confidence of nurses in the system and in the data it contains. Nurses may well be willing to pay the price of using the system when they believe real benefits will result. One nurse in this study commented on this relationship, saying that for personal use, she would use a conventional pen, but

for clinical data, she would use the digital pen because of greater accuracy, convenience, and completeness: "*Even though it takes extra steps … it is worth it.*"

7.4.2. For Developers

This study also has implications for developers. First is the importance of usability testing in the real world. As this study illustrates, even a thoughtfully designed and functional device such as this digital pen and paper system was discovered to have significant shortcomings due to some of its physical characteristics. These shortcomings are to some degree unique to these nurses in this setting. To improve technology, such as in this system, it is necessary to first conduct usability studies in real healthcare environments and second, to repeat testing and redesign in an iterative fashion.

In addition, the designer and the developer must put themselves in the place of the user. In the context of nursing work, this means that patient care is the focus and that documentation is but one of many important, simultaneous tasks relating to multiple patients, which must be performed under a variety of constraints. To do otherwise can produce an idealized model of workflow that imposes unnecessary constraints that limit usability. To avoid such problems, developers should include real users in the development process and allow for multiple possible workflows in using the device.

Two examples of how the digital pen increased redundant steps in nurses' real workflow were found. First, the digital pen and paper system currently has no barcode scanning function for patients' medical record number. Nurses were therefore required to write the patient's name and medical record number on each form for the system to recognize the patient. This redundant step could be easily eliminated by incorporating barcode technology into the digital pen and paper system. With such an integrated system,

nurses would be able to capture data already entered (e.g. patient identifiers) and also enter new data with handwriting. A second example concerns data transfer from pen to computer. As this study found, downloading data was an unnecessary extra step in nurses' workflow: though this step takes only a few seconds, it may be very significant for nurses who have multiple simultaneous tasks to perform or may be in an urgent situation. Automatic transfer of data using wireless technology could remedy this problem.

7.4.3. For Implementers

There also are implications for implementers, in terms of 1) completeness of implementation, 2) availability of the technology, 3) confidence of the users, 4) support: technical support of the system and moral support for the users. In this study, the incomplete implementation of the system (used for the Admission Database form but no other task) created problems, causing a disruption of workflow, as a nurse was required to consider which type of form should be used. Second, the limited availability of digital pens and docking stations also created problems, interrupting nurses' workflow as they stopped to return to the single docking station after every task. Third, the fragility and value of the pens was a distraction, causing nurses to worry about the pens rather than worry about their patients. Finally, the occurrence of system crashes and concerns by the nurses about possible data loss underscore the need for sufficient, immediately available technical support. Furthermore, nurses will feel more confident about the technology and be more likely to use the device when they can see that the system is successful and their data is secure. No matter how effective the device may be in isolation, these

implementation issues would need to be addressed for successful adoption and widespread use.

7.5. Implication for nursing practice and nursing informatics

Allen reports that many nurses view nursing documentation as routine work, a chore that does not provide benefit to their nursing work, but must be performed for regulatory reasons for the benefit of others. Though nurses recognize the value of the nursing record for nursing process, their attitudes have been less positive because it can be so difficult to find paper-based information when it is needed. (55). Nurses' perspectives toward nursing documentation in the present study were consistent with this view. Hopefully, successful implementation of technologies such as the digital pen and paper system can help to improve this situation for nurses.

Using a device such as the digital pen and paper system examined in this study, nurses will have greater flexibility in creating the nursing record. They could add to the clinical record not only the required documentation but also the important observations, concerns, and questions that nursing judgment and patient requirements suggest. This in turns leads to an electronic nursing record that contains richer clinical data, more useful to nursing practice and more immediately accessible to nurses. Furthermore, this enriched nursing record can better support research about nursing interventions and nursing outcomes, forming a sound basis for evidence-based practice in nursing.

8. Conclusion

Electronic health records (EHRs) are increasingly a routine part of clinical practice. New devices for interacting with information systems in clinical settings can help clinicians and patients realize the full benefits of the EHR. But first, these devices must be compatible with the work environment, tasks, and goals of clinical practice. Though this study showed that most nurses would prefer to use pens rather than keyboard, it does not mean that pens are suitable for EVERY nurse. Nurses must be able to choose the device most suitable to their work style, tasks, experience and abilities. A suitable spectrum of input devices would allow nurses whose typing is faster to use a keyboard as desired, while others whose writing is faster could use a pen-based system. By supporting nurses' preferences and abilities, nursing documentation would be less of a burden and the benefits of the EHR can be more fully realized.

This study found that nurses could foresee the potential benefits of the digital pen and paper system, but they found the system in its current form to have poor usability and to interfere with their work process. Bennett's model was used to help explain these findings in terms of the interaction of user, tool, task and environment. Usability testing gave important insights into the needs of nurses and the suitability of this technology. The study is an example of how a user-centered approach can improve our understanding of the real needs of nurses and contribute to the design of useful and usable technologies for healthcare.

9. References

1. Shortliffe EH, Perreault LE, Wiederhold G, Fagan LM. Medical informatics : computer applications in health care and biomedicine. 2nd. ed: Springer; 2001.

2. Sahlstedt S, Adolfsson H, Ehnfors M, Kallstrom B. Nursing process documentation--effects on workload and quality when using a computer program and a key word model for nursing documentation. Studies in Health Technology & Informatics 1997;46:330-6.

3. Shaw R, Coia JE, Michie J. Use of bar code readers and programmable keypads to improve the speed and accuracy of manual data entry in the clinical microbiology laboratory: experience of two laboratories. Journal of Clinical Pathology 1999;52(1):54-60.

4. Neuenschwander M, Cohen MR, Vaida AJ, Patchett JA, Kelly J, Trohimovich B. Practical guide to bar coding for patient medication safety. American Journal of Health-System Pharmacy 2003;60(8):768-79.

5. Douglas J, Larrabee S. Bring barcoding to the bedside. Nursing Management 2003;34(5):36-40.

6. Henricks WH, Roumina K, Skilton BE, Ozan DJ, Goss GR. The utility and cost effectiveness of voice recognition technology in surgical pathology. Modern Pathology 2002;15(5):565-71.

7. Mitchard H, Winkles J. Experimental comparisons of data entry by automated speech recognition, keyboard, and mouse. Human Factors 2002;44(2):198-209.

8. Kotani K, Horii K. An analysis of muscular load and performance in using a pen-tablet system. Journal of Physiological Anthropology & Applied Human Science 2003;22(2):89-95.

9. Spyglass Consulting Group. Study reveals more than 90% of nurses are reluctant to use tablet PC for bedside. paper, JAMIA 2004.

10. Lanway C, Graham P. Mobile documentation. Wireless PDAs boost job satisfaction for utilization review nurses. Healthcare Informatics 2003;20(10):80.

11. Fletcher LA, Erickson DJ, Toomey TL, Wagenaar AC. Handheld computers. A feasible alternative to paper forms for field data collection. Evaluation Review 2003;27(2):165-78.

12. Johnson C, Nolan MT. A guide to choosing technology to support the measurement of patient outcomes. Journal of Nursing Administration 2000;30(1):21-6.

13. Laerum H, Karlsen TH, Faxvaag A. Effects of scanning and eliminating paper-based medical records on hospital physicians' clinical work practice. Journal of the American Medical Informatics Association 2003;10(6):588-95.

14. Anoto. Digital Pen and Paper System. http://www.anoto.com/ 2004.

15. Shackel B. The concept of usability. In: Bennett J, Case D, Sandelin J, Smith M, editors. Visual display terminals. Englewood Cliffs: Prentice-Hall; 1989. p. 45-87.

16. Iwarsson S, Stahl A. Accessibility, usability and universal design--positioning and definition of concepts describing person-environment relationships. Disability & Rehabilitation 2003;25(2):57-66.

17. Staggers N. Essential principles for evaluation the usability of clinical imformation systems. Computers in nursing. 1995;13(5):207, 211-3.

18. Bennett J. Visual Display Terminals: Usability Issues and Health Concerns. Englewood Cliffs New Jersey: Prentice-Hall; 1984.

19. Nielson J. Usability Engineering. Cambridge: Academic Press; 1993.

20. Bevan N, Kirakowski J, Maissel J. What is usability? In: Proceedings of the 4th International conference on HCI; 1991 September; Stuttgart; 1991.

21. ISO 9241-11. Ergonomic requirements for office work with visual display terminals (VDTs) -- Part 11: Guidance on usability. 1998.

22. Dumas JS, Redish JC. A Practical Guide to Usability testing. Revised ed. Portland: Intellect Ltd; 1999.

23. Staggers N, Mills ME. Nurse-computer interaction: staff performance outcomes. Nursing Research 1994;43(3):144-50.

24. Yao P, Gorman PN. Discount usability engineering applied to an interface for Web-based medical knowledge resources. Proceedings / AMIA ... Annual Symposium. AMIA Symposium. 2000:928-32.

25. Wiklund ME. Usability in Practice. Cambridge: Academic Press; 1994.

26. Rubin J. Handbook of usability testing. New York: John Wiley & Sons; 1993.

27. Goossen WT, Epping PJ, Dassen T. Criteria for nursing information systems as a component of the electronic patient record. An international Delphi study. Computers in Nursing 1997;15(6):307-15.

28. Butler MA, Bender AD. Intensive care unit bedside documentation systems. Realizing cost savings and quality improvements. Computers in nursing. 1999;17(1):32-8.

29. Pabst MK, Scherubel JC, Minnick AF. The impact of computerized documentation on nurses' use of time. Computers in nursing. 1996;14(1):25-30.

30. Allen D, Davis M. A computerized CIS enhances bedside intensive care. Nursing management. 1992;23(7):112I-112J, 112N, 112P.

31. Hendrickson G, Kovner CT. Effects of computers on nursing resource use. Do computers save nurses time? Computers in nursing. 1990;8(1):16-22.

32. Bradshaw KE, Sittig DF, Gardner RM, Pryor TA, Budd M, Latter Day Saints H. Computer-based data entry for nurses in the ICU. M.D. computing : computers in medical practice. 1989;6(5):274-80.

33. Urden LD, Roode JI. Work sampling. A decision-making tool for determining resources and work redesign. Journal of Nursing Administration 1997;27(9):34-41.

34. Axford RL, Carter BE. Impact of clinical information systems on nursing practice. Nurses' perspectives. Computers in nursing. 1996;14(3):156-63.

35. Pierpont GL, Thilgen D. Effect of computerized charting on nursing activity in intensive care. Critical care medicine. 1995;23(6):1067-73.

36. Logitech. Logitech io Digital Writing System. http://www.logitech.com/ 2004.

37. Mi-Co. Mi-Forms. Mobile Data Capture Software System. http://www.mi-corporation.com/ 2004.

38. Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of infromation technology. MIS Quarterly 1989;13(3):318-340.

39. Taylor S, Todd PA. Understnading information technology usage: a test of competing models. Information systems research 1995;6(2):144-176.

40. Moore G, Benbasat I. Development of an instrument to measure the perceptions of adopting an information technology innovation. Information systems research 1991;2(3):192-222.

41. Morris M, Dillon A. The influence of user perceptions on software utilization: Application and evaluation of a theoretical model of technology acceptance. IEEE software 1997;14(4):58-6.

42. Ammenwerth E, Kaiser F, Wilhelmy I, Hofer S. Evaluation of user acceptance of information systems in health care--the value of questionnaires. Studies in Health Technology & Informatics 2003;95:643-8.

43. Taylor H. An exploration of the factors that affect nurses' record keeping. British Journal of Nursing 2003;12(12):751-4.

44 Ammenwerth E, Buchauer A, Bludau B, Haux R. Mobile information and communication tools in the hospital. International Journal of Medical Informatics 2000;57(1):21-40.

45. Graeber S. Application of clinical workstations: functionality and usability. Clinical Performance & Quality Health Care 1997;5(2):71-5.

46. Hobbs SD. Measuring nurses' computer competency: an analysis of published instruments. In: Computers, informatics, nursing : CIN.; 2002. p. 63-73.

47. Ammenwerth E, Mansmann U, Iller C, Eichsteadter R. Factors affecting and affected by user acceptance of computer-based nursing documentation: results of a two-year study. Journal of the American Medical Informatics Association : JAMIA. 2003;10(1):69-84.

48. Dillon TW, Lending D, Crews TR, 2nd, Blankenship R. Nursing self-efficacy of an integrated clinical and administrative information system. Computers, informatics, nursing : CIN. 2003;21(4):198-205.

49. Quinzio L, Junger A, Gottwald B, Benson M, Hartmann B, Jost A, et al. User acceptance of an anaesthesia information management system. European Journal of Anaesthesiology 2003;20(12):967-72.

50. Barr BJ. Managing change during an information systems transition. AORN Journal 2002;75(6):1085-92.

51. Ammenwerth E, Iller C, Mahler C. IT-adaption and the interaction of task, technology and indivisuals: a theory of FITT and a case study. In: ITHC; 2004; Portland, OR; 2004.

52. Ammenwerth E, Iller C, Mansmann U. Can evaluation studies benefit from triangulation? A case study. International Journal of Medical Informatics 2003;70(2-3):237-48.

53. Nielson J. Guerrilla HCI: Using Discount Usability Engineering to Penetrate the Intimidation Barrier. http://www.useit.com/papers/guerrilla_hci.html 1994.

54. Grudin J. Social evaluation of the user interface: who does the work and who gets the benefit. In: Proceedings of INTERACT 87: IFIF Conference on Human-Computer Interaction; 1987; Stuttgart, Germany; 1987.

55. Allen D. Record-keeping and routine nursing practice: the view from the wards. Journal of Advanced Nursing 1998;27(6):1223-30.

10. Appendices

10.1. Appendix A. Environment Setting

Labor and Delivery unit layout with dedicated computer

Computer cable and cradle connection

Close up of cradle and pen

Digital pens with labels

Location of admission forms

Charting at bedside and nursing station

10.2. Appendix B. Questionnaires:

Digital Pen vs. Conventional Pen

"1": Digital pen is **much better** than Conventional pen
"2": Digital pen is **better** than Conventional pen
"3": Digital pen is **slightly better** than Conventional pen
"4": Digital pen is **the same** as Conventional pen
"5": Conventional pen is **slightly better** than Digital Pen
"6": Conventional pen is **better** than Digital pen
"7": Conventional pen is **much better** than Digital pen

1. **Using which pen in my job would increase my productivity?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

2. **Using which pen would improve my job performance?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

3. **I would find which pen useful in my job?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

4. **Which pen would be easier for me to become skillful at using it?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

5. **Using which pen is a good idea?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

6. **Using which pen would be unpleasant?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

7. **Which pen would I find it easier to get to do what I want to do?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

8. **Using which pen would fit into my work style?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

9. **Using which pen in my job would enable me to accomplish tasks quickly?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

10. **I would find which pen to be more flexible to interact with**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

11. **Using which pen is a foolish idea?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

12. **Using which pen would make it easier to do my job?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

13. **The setup of which pen would be compatible with the way I work?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

14. **Using which pen would enhance my effectiveness on the job?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

15. **Which pen would fit better with the way I work?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

16. **Learning to operate which pen would be easier for me?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

17. **Which pen would I find easier to use?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

18. **My experience with which pen is easier for me to understand?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

19. **I like the idea of using which pen?**

1	2	3	4	5	6	7
Digital Pen			The same			Conventional Pen

Perceived Usefulness: 1, 2, 3, 9, 12, 14

Perceived Ease of Use: 4, 7, 10, 16, 17, 18

Compatibility: 8, 13, 15

Attitude: 5, 6, 11, 19

10.3. Appendix C. Interview Questions:

Group 1

Who: Where: When:

1. What do you think about the pen? (size, cap, direction, ink color)
2. What are the features you like or you don't like?
3. Do you think it is easy to use or not easy to use? Why? How about the leaning curve?
4. How doest it affect your work? Does it change the way you work?
5. Another nurse mentioned about the extra step to download the data, what do you think?
6. What do you think the advantages or disadvantages of the digital pen? How about the system for the pen?
7. Do you have any opinions comparing conventional pen and digital pen? Any difference?
8. If you could choose computer charting, PDA, tablet PC, digital pen, and conventional pen for charting, which will you choose? Why?
9. Any comment about the study?

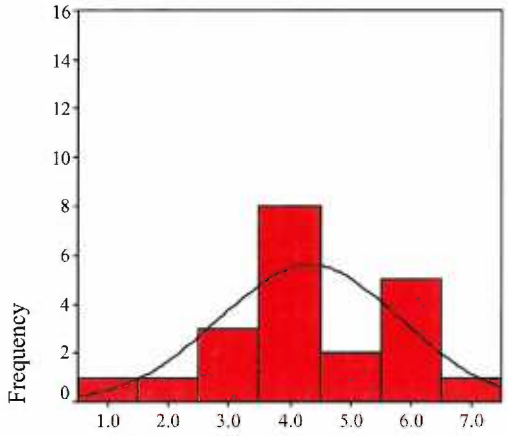
Group 2

Who: Where: When:

1. What do you think about the pen? (size, cap, direction, ink color, vibration)
2. What are the features you like? What are the features you don't like?
3. Do you think it is easy to use or not easy to use? Why? How about the leaning curve?
4. How does it affect your work? Does it change the way you work?
5. What happens when you are very busy? Do you still use the pen when you are busy? Why?
6. Do you use the pen less at the end of the study?
7. Another nurse mentioned about the extra step to download the data, what do you think?
8. What do you think the advantages or disadvantages of the digital pen? How about computer connection for the pen?
9. Does the experience of others who used the pen influence the way you use the pen? How about the opinion about the pen?
10. Do you have any opinions comparing conventional pen and digital pen? Any difference?
11. If you could choose computer charting, PDA, tablet PC, digital pen, and conventional pen for charting, which will you choose? Why?
12. Do you sometimes take the digital form, but not fill it out?
13. Any comment about the study?

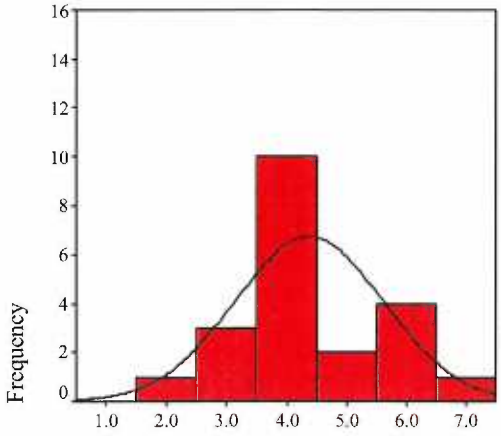
10.4. Appendix D. Summary of Data for all Questionnaire Items

N = 21
Median = 4.00
Mean = 4.33
SD = 1.49



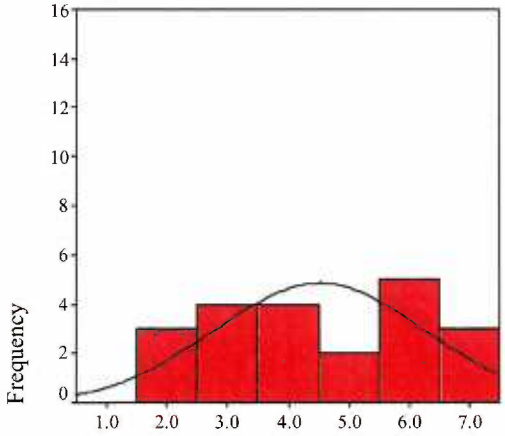
Q1

N = 21
Median = 4.00
Mean = 4.4
SD = 1.24



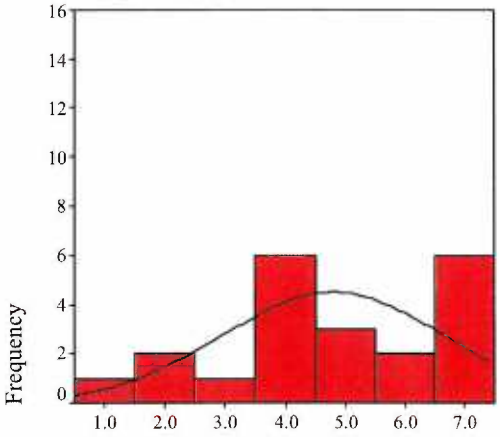
Q2

N = 21
Median = 4.00
Mean = 4.5
SD = 1.72



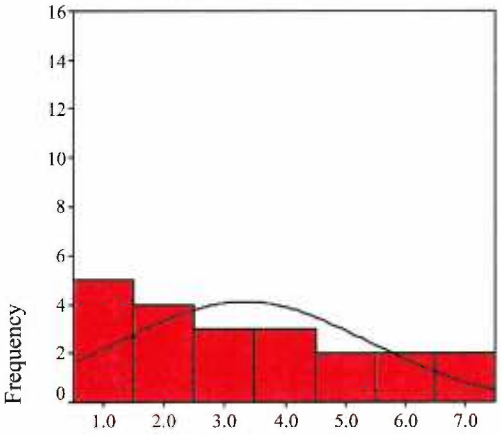
Q3

N = 21
Median = 5.00
Mean = 4.8
SD = 1.86



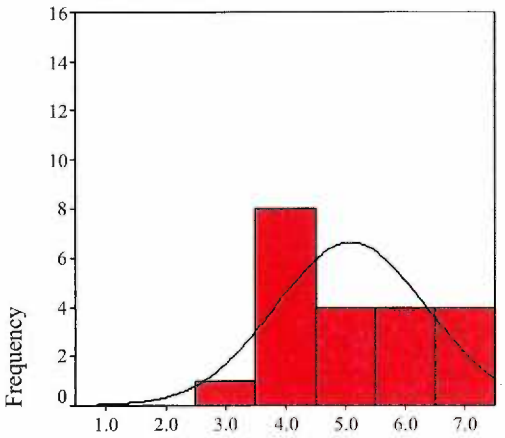
Q4

N = 21
Median = 3.00
Mean = 3.3
SD = 2.03



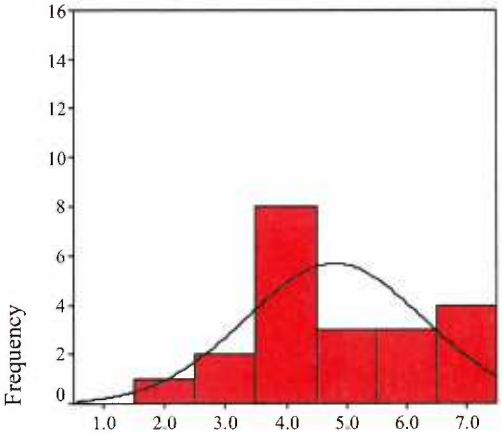
Q5

N = 21
Median = 5.00
Mean = 5.1
SD = 1.26



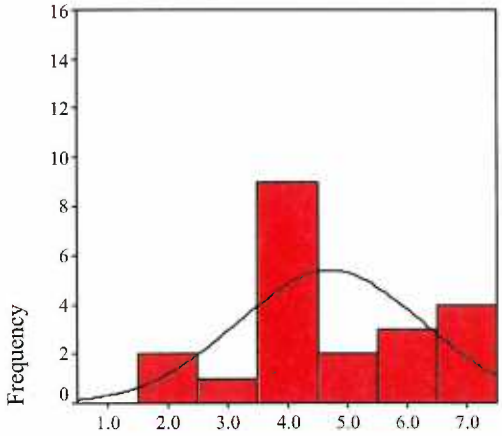
Q6

N = 21
Median = 4.00
Mean = 4.8
SD = 1.47



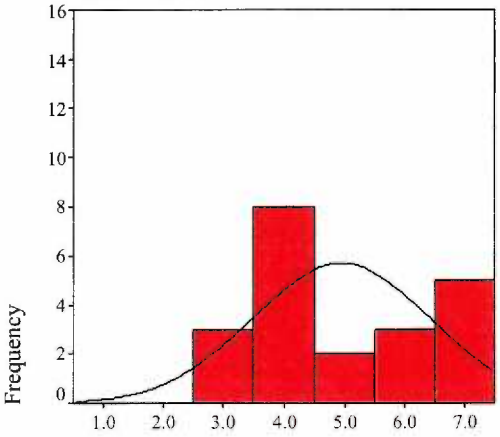
Q7

N = 21
Median = 4.00
Mean = 4.7
SD = 1.55



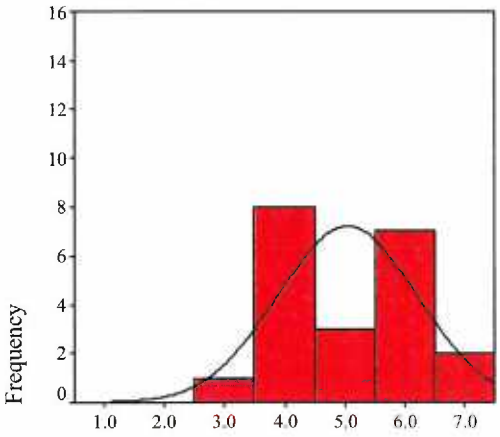
Q8

N = 21
Median = 4.00
Mean = 5.0
SD = 1.47



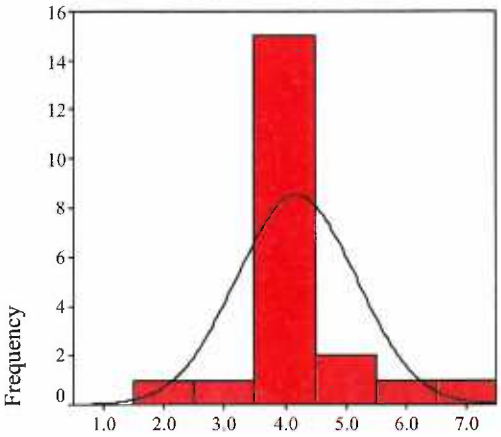
Q9

N = 21
Median = 5.00
Mean = 5.0
SD = 1.16



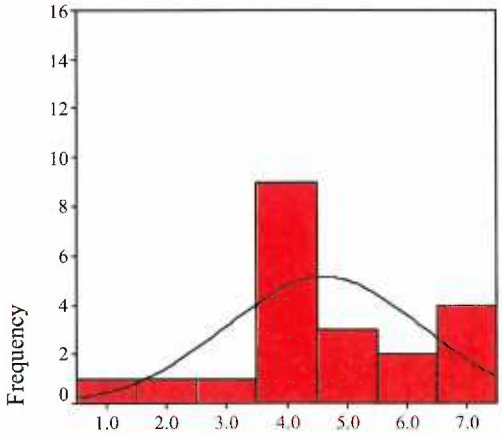
Q10

N = 21
Median = 4.00
Mean = 4.2
SD = 0.98



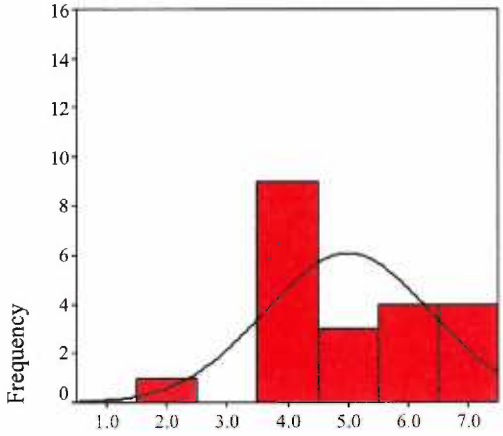
Q11

N = 21
Median = 4.00
Mean = 4.6
SD = 1.63



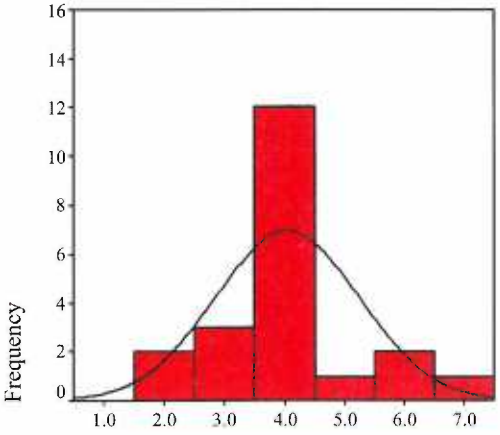
Q12

N = 21
Median = 5.00
Mean = 5.0
SD = 1.38



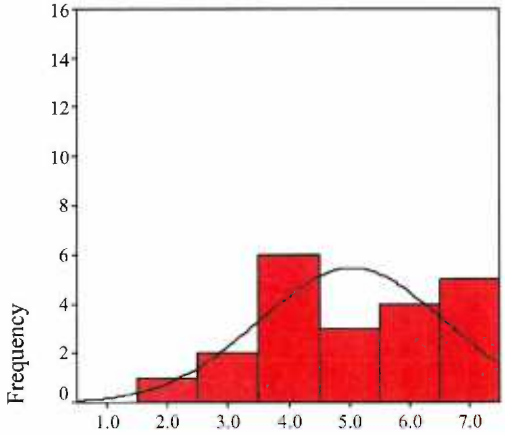
Q13

N = 21
Median = 4.00
Mean = 4.0
SD = 1.20



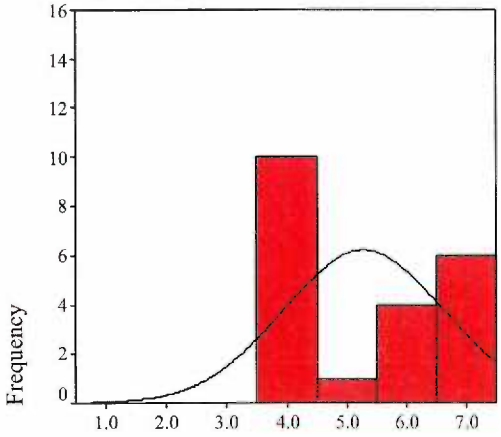
Q14

N = 21
Median = 5.00
Mean = 5.0
SD = 1.53



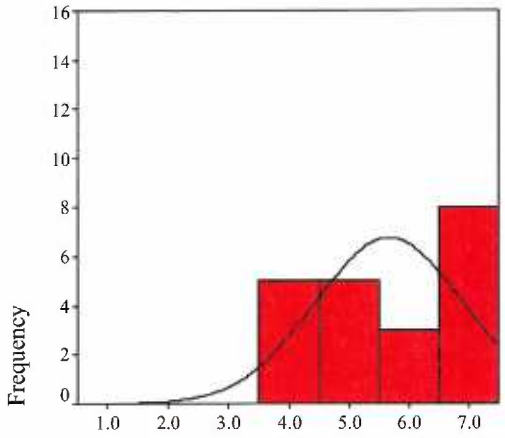
Q15

N = 21
Median = 5.00
Mean = 5.3
SD = 1.35



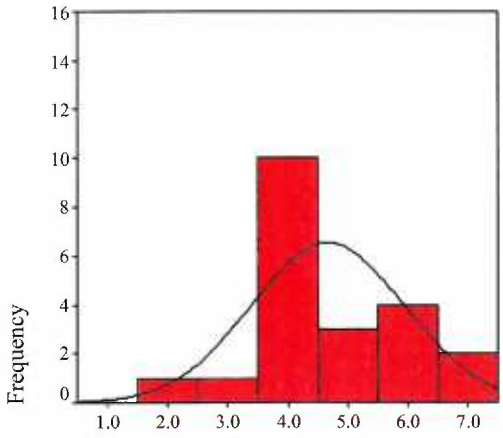
Q16

N = 21
Median = 6.00
Mean = 5.7
SD = 1.24



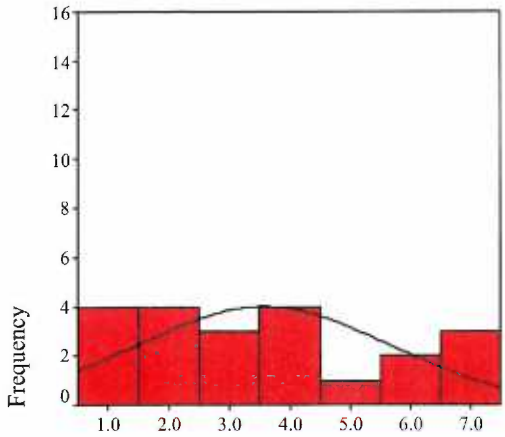
Q17

N = 21
Median = 4.00
Mean = 4.7
SD = 1.28



Q18

N = 21
Median = 3.00
Mean = 3.6
SD = 2.09



Q19