Nurses' Perceived Comparative Usefulness between an Icon-based Electronic Clinical Dashboard and an Integrated Clinical System

A Dissertation
SUBMITTED TO THE FACULTY OF THE
UNIVERSITY OF MINNESOTA
BY

Jason Jeffrey Fratzke

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

Connie White Delaney, Advisor

June 2019

Acknowledgements

I gratefully acknowledge all the wonderful PhD nursing student colleagues of the University of Minnesota with whom I had the opportunity to share in this journey. There is no substitute for the comradery that is shared with those living through the same experiences. It was an honor and pleasure to meet all of you. I wish each of you the best of luck in your life endeavors.

I want to acknowledge my mentor, friend, Doreen Frusti, for her unwavering support and encouragement to pursue my doctoral degree in nursing. Your prodding, persistence, and belief in me as a future leader in nursing set me on this path. I will always be grateful, thank you.

Lastly and by no means least, I want to acknowledge my in-laws, Wayne and Debra Berg for their support and encouragement during this journey. I am so appreciative for all you have done for my family and me.

Dedication

I dedicate this dissertation to my advisor Connie White Delaney, PhD, RN, FAAN, FACMI, FNAP. Her guidance, patience, and attention to detail facilitated the completion of this innovative dissertation research. I am also indebted to the members of my examination committee, Drs. Thomas Clancy, Karen Monsen, and Sharon Tucker. They offered support and advice that was integral to my research. For that, I am profoundly appreciative.

I also dedicate this dissertation to my loving immediate family: Alesia, Jaecan, Amelia, and Jensen; my dear wife and wonderful children have supported me and been so understanding during this lengthy journey. I am incredibly proud to be your husband and father. A wondrous and full life is yours for the taking and I have no doubt you will each find the right path. My wife deserves special gratitude for taking added responsibility for our family, despite having her own fulltime professional career. This accomplishment would not have been possible without her. I love you all.

Finally, I dedicate this dissertation to my father and mother, Jeffrey and Gayette Fratzke, for their unconditional love, timely wisdom, support, continuous encouragement, and unending reinforcement that I can achieve anything I set my mind to. My parents provided the foundation that has allowed me to appreciate and confront all the opportunities life has given me, good and bad. They taught me that discipline, determination, and dedication would take me far in life. I am forever grateful and love you both.

Abstract

Nurses place a high value on spending as much time as possible directly caring for patients. Optimizing the health system to allow nurses adequate patient-centered time is essential for improved patient experiences, improved health of populations, reducing the overall cost of healthcare, and improving the work life of health care clinicians and staff. As nurses are asked repeatedly to do more with less in a constantly changing and demanding work environment, it will be essential that technology is viewed by nurses as a partner. Pivotal to a successful integration of the technology is understanding nurses' intentions to use the technology within their practice.

The purpose of this research is to compare nurses' perceived usefulness (PU), perceived ease of use (PEU), and workload burden for the Integrated Clinical System (ICS) and the icon-based electronic clinical dashboard system, INFUZE. The comparison of the nurses' perceptions between the ICS and INFUZE, was conducted via a retrospective descriptive, comparative mixed-methods design using secondary data. Data from a private clinical database representing 189 registered nurses (RNs) practicing from September 2012 through December 2012 was used in the secondary data analysis. Data compared RNs' perceptions of the current electronic health record (EHR) system and a home-grown (native) prototype called INFUZE. The dataset included quantitative measurement regarding usefulness, ease of use, and cognitive workload as measured by either a five-point (Technology Assessment Model [TAM]) or seven-point (NASA Task Load Index [TLX]) Likert scale. To complement and provide further insight, focus group

data was also included and analyzed using a constant comparative and content analysis. The mixed-method design compared nurses' perceptions of the availability of patient data between two systems and measured the need for timely access to pertinent patient data. New insights for clinical data use to support nurses were discovered.

This descriptive, comparative mixed methods study compared nurses' PU, PEU, and workload burden for the ICS and the icon-based electronic clinical dashboard system, INFUZE. The research approach used an extended conceptual framework, utilization the TAM and NASA TLX models and the inclusion of external variables of support resources, experience, demographics, and relevance to task. The secondary dataset included ICS (N=131) questionnaire data INFUZE (n=85) questionnaire data complete between September 19, 2012 and January 31, 2013. Transcripts of three voluntary focus groups were analyzed using content analysis methods to synthesize the feedback of 13 nurse participants. For PEU and PU, ICS was favored over INFUZE. For workload, INFUZE was favored over ICS. Focus group analysis revealed that there would be value in implementing an integrated dashboard interface if it is helpful in consuming actionable data rapidly; however, if it is not helpful, the interface would be irrelevant and/or burdensome. Furthermore, nurses considered the learning curve for new technology burdensome.

In summary, the use of icons and/or dashboards tailored to the specific needs of nursing has potential to improve nurses' experience, if the dashboard is a seamless part of the workflow and is integrated within existing technology. Further research is needed to understand human-computer interaction for specific interfaces in situ, toward the goal of

developing an interface that is effective as an integrated and seamless companion to the core EHR.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction to the Study

Nurses of caliber need a high level of practice knowledge and the ability to obtain and apply current clinical data to prioritize patient care needs on an ongoing basis, particularly in the fast paced inpatient care setting (Franklin et al., 2017; Koch et al., 2012a; S. Lee & Huebner, 2017). Electronic charting systems should be designed to meet the needs of the nurses using them, to allow the nurses to be effective and efficient, and provide the safest care to patients (Norris, 2012). With the proliferation of upgraded or new EHR systems, nurses are concerned that EHR systems do not reflect the way they work and are influencing changes in how they practice (Duffy, 2015). Coupled with the daily challenges and frustrations in providing care, due, at least in part, to inefficient access to clinical data, lack of communication, and frequent interruptions, nurses are looking for help (O'Connor, Friedrich, Scales, & Adhikari, 2009). It is crucial for electronic systems to reprocess and provide essential health information to healthcare professionals in a comprehensive and organized manner that is conducive to quick and accurate decision making (K. Lee et al., 2017). New knowledge is needed to further understand the implications of electronic systems on nurses' abilities to effectively and efficiently use electronic data to care for patients (Wilbanks & Langford, 2014). With greater understanding, new applications can synthesize and present information in a brief and usable manner while also increasing nursing satisfaction and decreasing mental workload (Koch et al., 2012b).

Background of the Study

Health care systems have long struggled with inadequate communication techniques, leading to operational and clinical inefficiency (Doig, Drews, & Keefe, 2011). Following recommendations from the Joint Commissions, health care systems have prioritized strengthening communication among clinicians as a common goal (Tielbur et al., 2015). Multiple specialties and increasingly complex patients result in a wide variation in delivery of care, making communication an intricate process not easily captured by a single method (Manojlovich et al., 2015). Many communication issues pose significant risk to patients, such as clinician interruptions, delayed or unanswered responses to numeric pages, multiple unintegrated communication tools, lack of awareness regarding patient results, EHR systems with usability issues, and lack of contact information for clinicians (Popovici et al., 2015). These factors contribute to multi-tasking, the need to strive to remember important information, and attempting to communicate regularly and accurately to ensure efficient, safe, and patient-centered care (S. Lee & Huebner, 2017).

Nurses' ability to obtain accurate and timely clinical data from within the EHR is very valuable in providing efficient and safe care to patients (O'Connor, Friedrich, Scales, & Adhikari, 2009) and improving communication. The challenge is that nurses have to review and synthesize large quantities of electronic clinical information to make clinical decisions (Gurses, Xiao, & Hu, 2009), which is often difficult to obtain in the expansive EHR (Hyun, Johnson, Stetson, & Bakken, 2009). Different types of data need

to be presented in a readily understandable format to support quick assimilation and transformation into information and insight to guide action (Franklin et al., 2017; Dowding et al., 2017).

One possible solution for this situation is an icon-based electronic clinical dashboard (Hurley et al., 2009). Effective visualization can support better detection, interpretation, understanding, and evaluation of information for real-time decision-making (Franklin et al., 2017). An icon-based electronic clinical dashboard would collect and display pertinent patient care clinical data in the form of icons displayed on a screen (Salman et al., 2012). Tasa, Ozcan, Yantac, & Unluer (2008) note an icon-based electronic clinical dashboard should only provide the clinical patient care data needed to meet the needs of the user to make clinical decisions and complete care. Unless icons are meaningful and identifiable, they may cause unexpected selection errors, resulting in serious problems if the icon (color, shape, movement, etc.) inaccurately communicate information to the viewer (Salman et al., 2012). For the nurse, the expectation is that patient care clinical data can be easily and quickly accessed and assessed by viewing an icon-based electronic clinical dashboard for each individual patient instead of searching disparate applications in the collective EHR (Hurley et al., 2009). Visualization tools are specifically designed to assist our visual system to more efficiently process detail that might otherwise require significant cognitive effort (Franklin et al., 2017).

The proliferation of health data and the multitude of electronic systems continuously inundating nurses contribute to information overload (S. Lee, Kim, & Monsen, 2015). Nurses are often responsible to simultaneous monitor, interpret, and act

on real-time data from sources such as physiologic monitors, ventilators, infusion pumps, bed alarms, nurse call systems, and test results (S. Lee & Huebner, 2017; Tan et al., 2013). Clinical dashboards are designed for use by individual clinicians for surveillance and to guide practice decisions at the point of care by displaying relevant, timely, and usable data (Dowding et al., 2015). A nursing icon-based electronic clinical dashboard can create a single, consolidated view of disparate clinical and operational data, allowing for efficiency and speed in its acquisition when providing patient care (K. Lee et al., 2017; Sidebottom et al., 2012).

A critical review of the literature, with the publication timeframe limited back to the year 2007, provided only twelve studies between the years 2009 to 2017 with examples of nurses using icons (visual representation) and/or digital dashboards to fully utilize and manage clinical data. The studies provided evidence that nurses gained improved ability to effectively synthesize significant amounts of clinical data using icons and/or digital dashboards. A common theme through the studies spoke of the day-to-day challenges nurses encounter navigating and integrating all the streams of data and information from multiple sources regarding their patients (Franklin et al., 2017; Hurley et al., 2009; Koch et al., 2012(a); S. Lee & Huebner, 2017; S. Lee, Kim, & Monsen, 2015; Sidebottom et al., 2012; Tan, Hii, Chan, Sardual, & Mah, 2013; Zaydfudim et al., 2009). Several of the studies established the importance of using an integrated display or dashboard to sufficiently allow the nurses to visualize clinical data more efficiently or in an actionable manner (Batley, Osman, Kazzi, & Musallam, 2011; Dowding et al., 2015; Franklin et al., 2017; Koch et al., 2012a; Koch et al., 2012b; K. Lee et al., 2017; S. Lee,

Kim, & Monsen, 2015; Sidebottom, Collins, Winden, Knutson, & Britt, 2012; Zaydfudim et al., 2009a). Having an easy-to-interpret visual display to provide a notification when a predefined value deviated from the norm minimized adverse events and provided clinical decision support to improve efficiency and quality (Tan et al., 2013). While the reviewed studies provided evidence that the use of icons and/or digital dashboards allow efficient data consumption and viewing, little attention was given to the comparison of current EHR viewing tools against an icon-based electronic clinical dashboard system.

The ICS is comprised of approximately 35 applications and modules used to support all aspects of the clinical practice within a large Midwestern academic medical center. The applications support documentation, ordering, viewing, imaging, clinical decision support, communication, scheduling, billing, medication management, and reporting. The various vended and homegrown applications are accessible through desktop workstations located in workrooms, nursing stations, and patient rooms. Secure access is required to log-in into ICS prior to utilizing any of the applications. Treating and caring for the needs of patients requires accessibility to multiple separate applications and/or modules to view each patient's status, results, and information during hospitalization.

INFUZE is an application designed to collect and display pertinent, individualized, clinical and operational patient care data in the form of icons displayed on a screen. Each icon's individualized presentation characteristics (i.e., color, shape, blinking, etc.) have a specific meaning and communicate information to the viewer

without compromising patient confidentiality. Nurses are able to access information either through passive viewing of the dashboard on wall-mounted displays or by using a desktop computer. The password-protected desktop computer, provides enhanced capability to access additional detailed information when the cursor hovers over the icons. The INFUZE board displays in a geographical manner based on the individual unit, represented as rectangular patient rooms. Within each of the rooms, icons actively display when a patient is admitted into the bed. The icons shown in Figure 1 represent portions of key clinical and operational data from over ten separate clinical and operational systems the nurses must interact with to provide patient care on a daily basis. During development of the INFUZE application, a select number of nurses were used as subject matter experts to assure accuracy and validity of the INFUZE data as compared with the source system. The data retrieval is near real-time, with the screen automatically refreshing the data every two minutes, if not done manually (sooner) by the individual user. The use and concept of clinical viewers/dashboards for research is not new. However, the literature review did not find any studies comparing the nurses' PU, PEU, and workload burden between a core EHR and an icon-based electronic clinical dashboard system.

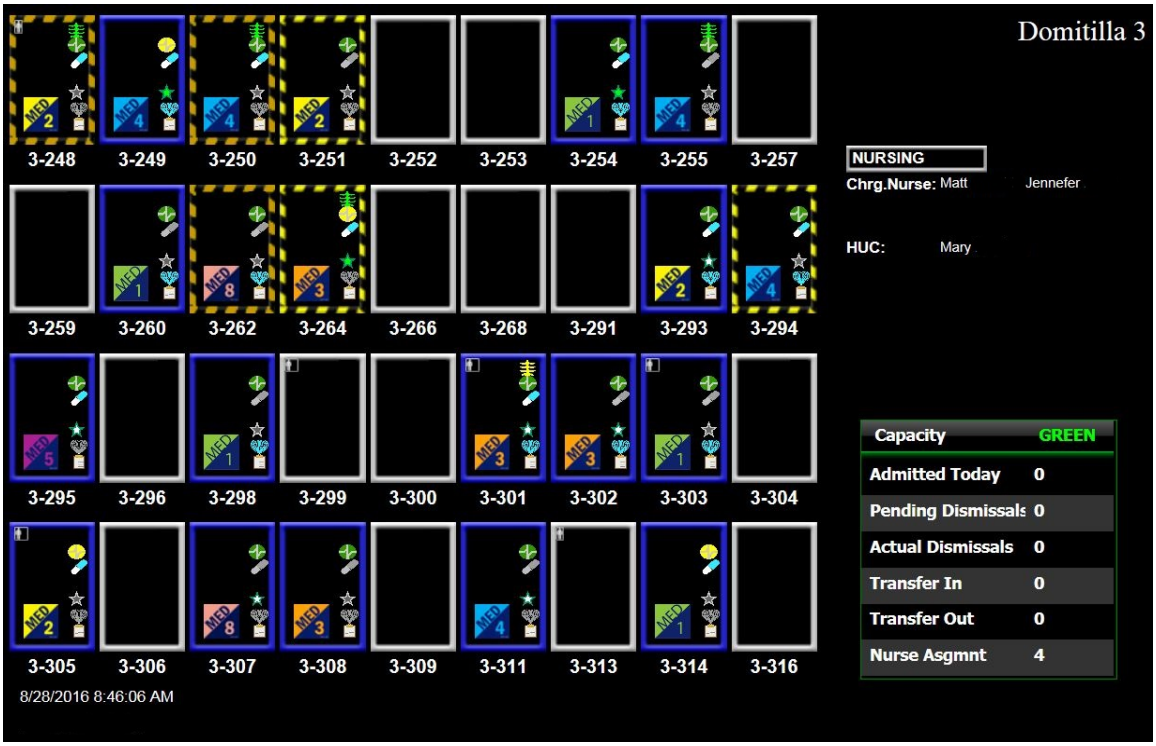

Figure 1. INFUZE graphical display for nurses.

Nurses recognize a patient's changing conditions through physical and verbal assessments, communication with other team members, and/or physiologic data. Nurses also must frequently access the EHR to ascertain if any updates or new orders have been placed by the provider, which could impact patient care and treatment. INFUZE has the potential to integrate disparate clinical and operational key data, providing nurses access to real-time situational awareness (SA).

Table 1

INFUZE Icon Style Guide

Icon	Icon Name	Color State	Description
	Service	Grey	Primary Service Care for Patient
	Nurse	Grey	No Nurse Assigned
	Nurse	Yellow/Grey	Assigned Nurse
	Nurse	Yellow/Green	Temporary Coverage by Second Nurse
	Vitals	Grey	No Vital Signs Recorded this Admission
	Vitals	Green	Normal Vital Signs
	Vitals	Red	At least One Value is Abnormal
	Medications	Grey	No Orders During Current Admission
	Medications	Green	All New Medication Orders Profiled
	Medications	Blue	New Medication Order
	Medications	Red	Stat Medication Order
	Medications	Red w/clock	Scheduled Medication Late
	Labs	Grey/Grey	No Results for this Admission - 12 hours
	Labs	Grey/Orange	No Results for this Admission - New Results Pending

(continued)

Icon	Icon Name	Color State	Description
	Labs	Green/Grey	All Results Back and Normal
	Labs	Green/Orange	Normal Results Back - New Results Pending
	Labs	Yellow/Grey	Abnormal result - At least One Value Moderately
	Labs	Yellow/Orange	Abnormal result (Moderate) - New Results Pending
	Labs	Red/Grey	Critical Lab Value - At Least One Value is Critical
	Labs	Red/Orange	Critical Lab Value - New Results Pending
	Lab Ordered	Grey	No Orders Since Admission
	Lab Ordered	Blue	New Order Since Admission
	Lab Ordered	Red	New Stat Order
	Cares	Grey	No Care Ordered during Current Admission
	Cares	Blue	New Care Order
	Cares	Green	All Cares RN Reviewed
	Images	Grey	No Images this Admission
	Images	Blue	New Order and/or Past Orders with Notes
	Images	Green	All Orders with Notes
	Back Soon	Blank	Patient Available

(continued)

Icon	Icon Name	Color State	Description
	Room Closed	N/A	Closed for cleaning
	Fall Risk w/Injury	N/A	Fall Risk w/Injury
	Back Soon	Blank	Patient Available
	Room Closed	N/A	Closed for cleaning
	Fall Risk w/Injury	N/A	Fall Risk w/Injury
	Fall Risk	N/A	Fall Risk
	DNR/DNI	Grey	No Documentation
	DNR/DNI	Red/Green	DNR
	DNR/DNI	Green/Red	DNI
	DNR/DNI	Red/Red	DNR and DNI
	Infusion Pump	Grey	No Active Pump Assigned
	Infusion Pump	Spinning Green	Infusing
	Infusion Pump	Green/Red Pause	Manually Paused
	Infusion Pump	Red Flashing	Error Stopped
	Infusion Pump	Battery Low	Low Battery Alarm Sounding
	Dietary	Grey	No active diet order

(continued)

Icon	Icon Name	Color State	Description
	Dietary	Green	Documented diet order
	Dietary	Green/Red	NPO diet order
	Discharge	Grey	Status of Patients Discharge
	Note Pad	Grey	Ghost place holder
	Note Pad	Green	Free text
	Transplant Day	Grey	Ghost Place Holder
	Transplant Day	Green	Getting Transplant
	Chemo Day	Grey	Ghost Place Holder
	Chemo Day	Yellow	Getting Chemo
	Dietician	Grey	Ghost Place Holder
	Dietician	yellow	Dietician Needed
	Dietician	Green	Dietician Assessed
	Interpreter	Grey	Ghost Place Holder
	Interpreter	Green	Interpreter needed
	Blood Draw	Grey outline	Ghost Place Holder
	Blood Draw	Red outline	Blood Draw needed
	Blood Draw	Red/Green	Blood Draw Complete

Note. DNR = do not resuscitate; DNI = do not intubate; Chemo = chemotherapy; N/A – not applicable; w/injury – with injury; NPO = nothing by mouth.

Problem Statement

While a great deal of EHR systems integration has occurred, nurses are faced with an enormous amount of data overload impacting efficiency and their ability to find crucial clinical data (K. Lee et al., 2017). Nurses value their time and desire to increase their productivity to remain efficient in a constantly changing and demanding work environment. To do so, nurses want to: (1) document data once and use the data several times, (2) receive reminders or alerts when new information is available, and (3) have an easy method to retrieve clinical information (Hyun, Johnson, Stetson, & Bakken, 2009). The use of a dashboard could be a promising tool for improving the speed and accuracy of clinical decisions in the complex patient care environment (Schall et al., 2017).

Conceptual Framework

Technology Acceptance Model. The Technology Acceptance Model (TAM) was developed to provide a framework for evaluating new systems in the business and technology sector to ensure data collection is consistent even when applying to different samples, technologies, and environments (Venkatesh, 2000). The foundation of TAM originally included five constructs: PU, PEU, attitude toward using, intention to use, and actual system use (Davis, Bagozzi, & Warshaw, 1989; Hyun et al., 2009; Kowitlawakul, Chan, Pulcini, & Wang, 2015; Venkatesh, 2000). In adoption of a technology, user PU of the technology and PEU, are the two important areas of TAM (Ehteshami, 2017). Davis (1989) defined PU as "the degree to which a person believes that using a particular system would enhance his or her job performance." (p. 320) Davis (1989) defined PEU as

"the degree to which a person believed that using a particular system would be free of effort." (p.320) Davis et al., (1989) noted three benefits in using the TAM: the ability to evaluate the system, the ability to create modifications to increase usability and usefulness, and the ability to identify if further purchases of the technology are beneficial.

NASA Task Load Index. The National Aeronautics and Space Administration (NASA) Task Load Index (TLX) provides a method to measure nurses' workload. The NASA TLX uses six dimensions representing the "workload" experienced by the individuals performing the tasks, i.e., the demands of the users' mental, physical, and temporal capabilities, as well as assessment of effort, performance, and frustration, all of which impact the individuals' PEU (Hart, 2006). The mental demand assesses how much cognitive thinking effort users will expel to use the system. The physical demand is the assessment of how much body activity users will apply. The temporal demand is the users' interpretations or assessments of "pressure" or "pace" involved in using the system (Hart, 2006). Effort measures users' challenges in using the system (Hart, 2006). The performance measures the ability of the system to do what the user wants the system to do. The frustration assessment measures users' assessment of the system's ability to meet expectations (Hart, 2006). The NASA TLX is one of the most widely used instruments to assess overall subjective workload (Hoonakker, et al., 2011).

TAM and the NASA TLX. The TAM provides a relevant theoretical foundation, based on its prominent research application in healthcare. The use of the NASA TLX and the six dependent variables measuring workload has an impact on a nurses' PEU in

the TAM, both components within the conceptual framework depicted in Figure 2. In addition, external factors including support resources, experience, demographics, and relevance to task are other characteristics of the TAM that influence PU. The experience provides a background on individuals' comfort with technology, computers, and cell/smart phones. The demographic factor includes work location, age, gender, education level, and nursing experience. The last factor, relevance to task is the identification of the users' judgment in application within their given job (Venkatesh & Davis, 2000).

The TAM has been widely validated in past studies for user acceptance of computer technology in nursing and health informatics research (Song, Park, & Oh, 2015). The NASA TLX has been validated in past research by Hart, et al. (Hart & Staveland, 1988).

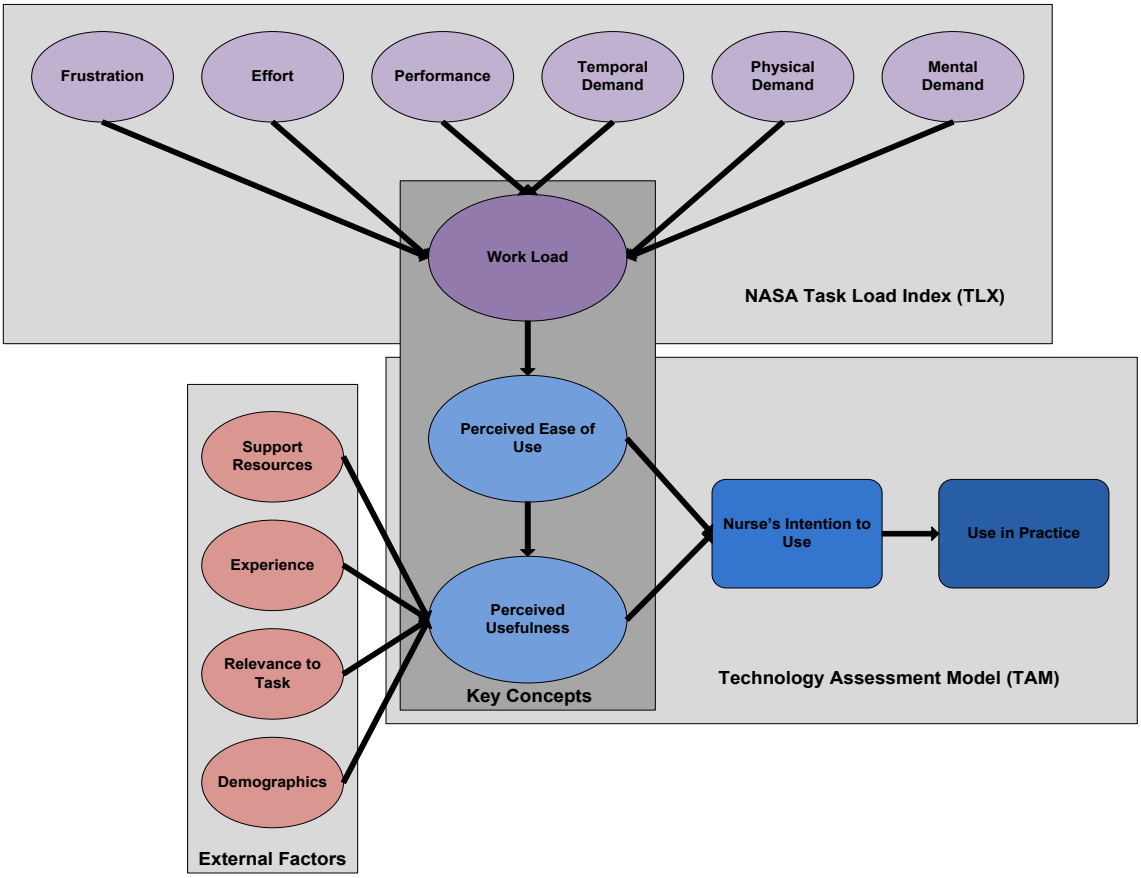

Figure 2. Conceptual Framework

Purpose and Specific Aims

The purpose of this research is to compare nurses' PU, PEU, and workload burden for the ICS and the icon-based electronic clinical dashboard system, INFUZE. The specific aims of this study are as follows:

Aim 1: Compare nurses' PEU of ICS to INFUZE to retrieve pertinent information relative to patient care and clinical operation of the unit;

Aim 2: Compare nurses' PU of ICS to INFUZE to retrieve pertinent information relative to patient care and clinical operation of the unit;

Aim 3: Compare nurses' perception of workload, using ICS versus INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit, and;

Aim 4: Compare nurses' perceptions of how their intention to use the tool was facilitated versus hindered, by utilizing the INFUZE Board.

Chapter 2: Literature Review

Purpose, Scope and Selection Criteria

The purpose of this review is to provide a synthesis of the state of the science regarding the types, use, and clinical data utilization and management of icon-based electronic clinical dashboards for nurses. The question to be addressed in this critical review is: What is the state of the science related to the types, use, and clinical data utilization and management through the use of icons (visual representation) and digital dashboards by nurses within the context of an EHR?

The scope of literature searched included research journals and articles, focusing on nurses' use of icons and dashboards in a healthcare setting. To ensure the technology was relative/linked to present day, a comprehensive search was performed from the year 2000 through 2017. The research studies were limited to those published in English. All sample sizes were included. Due to newness of the icon-based technology and consequently the limited numbers of research studies specific to the topic, both qualitative and quantitative studies were included. Opinion papers, studies not inclusive of nursing, in part or whole; studies lacking a form of visual representation, dashboards or related concepts; and articles requiring fees for access were excluded.

Database and Search Terms

The literature search was conducted using the CINAHL, Ovid MEDLINE, Web of Science, and Google Scholar databases. Manual searching by hand of key study's

reference lists was used to identify additional articles relative to this topic. Search terms directly relevant to the critical review question were used and included nurs*, icon*, dashboard*, visualization*, viewer*, hospital*, pictograph* integrated*, display*, and patient care.

Search Vocabulary

To address the question of use of icon-based electronic dashboards by nurses, the combined keywords "((icon*, or pictograph* or visualize* or viewer* or dashboard*) AND nurs*)," "((icon*, or pictograph* or visualize* or viewer* or dashboard*) AND hospital*)," "((icon*, or pictograph* or visualize* or viewer* or dashboard*) AND patient care)," and "((display*, or integrated*) AND nurs*)" were searched in the identified databases. This strategy retrieved the following number of results in each database: CINAHL, 1,463 articles; Web of Science, 435 articles; Ovid MEDLINE, 447 articles; and Google Scholar, 78 articles. When duplicates were removed, the number of unique articles was 1,572. These articles were initially evaluated by title and abstract as appropriate with a total of 57 meeting specific criteria. The final systematic review included 12 studies.

Evaluation/Quality Assessment

To evaluate and provide a critical analysis of the literature, the Matrix Method (Garrard, 2011) was used to evaluate the 12 studies in ascending chronological order using a structured abstracting form with 16topics: author, title, name of journal, year, country of origin, funding source, purpose of the paper, method, number of subjects,

subject characteristics, sample design, year data collected, results, citation, inclusion criteria, and exclusion criteria.

Study Characteristics

The 12 studies include quantitative and qualitative research. The countries of origin are: United States, Canada, Germany, Lebanon, Singapore, and South Korea. Publication dates of the studies ranged from the year 2009 through 2017. Funding sources for six of the studies were documented and included the Robert Wood Johnson Foundation (Hurley, Dykes, Carroll, Dykes, & Middleton, 2009); Draeger (Koch et al., 2012a); the Korea Health Technology R&D Project through the Korea Health Industry Development Institute, which was funded by the Ministry of Health & Welfare, Republic of Korea (K. Lee et al., 2017); University of Missouri-St. Louis (S. Lee, Kim, & Monsen, 2015); and the Agency of Healthcare Research and Quality, US Department of Health and Human Services (Zaydfudim et al., 2009b). While the relationship with Draeger was outlined by Koch et al. (2012a) in the study, a conflict of interest may unintentionally be present. The setting for ten of the studies were hospitals and two were home care only.

Ten study designs were cross-sectional in nature as a result of data collection of one or more groups during a specific timeframe. Cross-sectional studies by design are limited to data at a single point in time with no indication of the sequence of events, making it impossible to infer causality. The remaining two studies used a quasi-experimental design, which applies an intervention to a target population without the ability to randomly assign to treatment or control. This can create concerns regarding the

internal validity with the lack of control groups comparable at baseline. Five of the studies used a mixed method approach (Franklin, et al., 2017; Hurley et al., 2009; S. Lee, Kim & Monsen, 2015; S. Lee & Huebner, 2017; Tan et al., 2013), two of the studies were qualitative (Koch et al., 2012a; Sidebottom et al., 2012), and five of the studies were quantitative (Batley, Osman, Kazzi, & Musallam, 2011; Koch et al., 2012b; K. Lee et al., 2017; Schall et al., 2017; Zaydfudim et al., 2009b).

Analysis

The reviewed studies for this paper all included criteria that facilitated clinical data utilization and management through the use of icons (visual representation) and/or digital dashboards by nurses. An overview of the research can be grouped into three categories associated with key concepts of the conceptual model: usefulness, ease of use, and cognitive load.

Usefulness

The goal of the Franklin et al. (2017) study was "to develop visualizations of patient data to support clinicians' situation awareness of throughput." (p. 213) In the study, Franklin, et al. assert that if emergency department (ED) clinicians are able to obtain a high degree of SA, this provides a more global perspective on patient flow within the ED. What is the connection between SA and dashboards? The researchers created prototype dashboards that were presented to clinicians at 11 EDs within a single health system. A total of 19 participants provided feedback on the dashboards relative to their ability to improve SA and further support departmental workflow. Participants

included charge nurses, as well as a medical and ED directors. The feedback was used to further improve the dashboard prototype. Two trained evaluators performed a heuristic evaluation to determine overall adherence to standard design principles. Following implementation of the refined prototype dashboard, log-in data from the displays were used to evaluate total users, frequency of use overall, and number of views: 255 users used the dashboard, viewing the display on 17,559 occasions. Further anecdotal feedback was collected, providing examples on how the dashboard supported the recognition of patient throughput issues in the system. As another means of evaluating the effectiveness and comprehensiveness of the dashboard display, the researchers used eye-tracking software to recognize eye movement, indicating the patterns of information accessed on the displays. The data was used to make additional refinements and also help with training. While the researchers continue to improve upon the prototype dashboard, clinicians were able to make more appropriate decisions in the moment, based on the improved ability to make real-time decisions with improved SA.

Using an interrupted time series design, Zaydfudim et al., (2009) conducted a study to determine if the addition of an electronic dashboard measuring compliance with the ventilator-assisted pneumonia (VAP) bundle would reduce ventilator-acquired pneumonia. The VAP dashboard graphically displays compliance with the ventilator bundle parameters for each ventilated patient at appropriately timed intervals for each measure. Compliance with each parameter is reported by the bedside nurse in real time and verified by the surgical intensive care unit (SICU) charge nurse each shift. Compliance with an individual parameter is reported with green, yellow, and red

indicators. Green indicates that the parameter is in compliance. Red indicates that the parameter is out of compliance. Yellow warns that administration of the parameter is soon due. There were 121 cases of VAP in 7,907 ventilator days in the 10 quarters from January 2005 through June 2007. In comparison, there were 31 cases of VAP in 3,309 ventilator days in the 4 quarters between August 2007 and July 2008. The pre-intervention vs. post-intervention analysis demonstrated a 39% reduction in VAP rates from 15.2 to 9.3 per 1,000 ventilator days. The time series analysis allowed the researchers to adjust for secular trends and revealed an overall reduction in the VAP rates, with significant reduction in 2 of 4 quarters after implementing the electronic dashboard. Overall all the research design was well done. The most common drawback using a time series analysis is the inability to understand what is happening at that moment, because it does not use current data.

Using current inpatient EHR systems, Sidebottom et al., (2012), studied the nurses' perceptions, attitudes, and reactions to the system alerts. Further understanding of a nurse's attitude and preferences about the icon alerts will help establish guidelines for the design, introduction, and use of alerts in nursing practice. Using focus group participants recruited through existing nursing practice council meetings from three hospitals, the researchers asked 50 nurses about five different icon alert features. These five icon alerts were divided into two broad categories, banners and notifications of action required. Nurse evaluated two types of banner alerts, Kardex Report and Safety Overview Report. The three notification icon alerts nurses were asked to react to were the alert sections of the Kardex Report, Heart Failure Dashboard, and Pop-up alerts.

Based on each icon alert, the participants provided feedback about the reactions to the icon alert, how alerts help or hinder work, and suggestions for improvements. Individual transcripts were reviewed for each focus group, subdivided by meaning unit, each meaning unit was coded, and content was analyzed inductively for themes. Comments regarding the banners on the Kardex Report, indicated that nurses were aware of the banners but tended not to use them as a primary source of information about patient risks. The banners on the Safety Overview Report revealed that many nurses, number not defined by the authors, were unaware that the Safety Overview Report existed. While these same nurses reported little prior exposure to the Safety Overview Report, they gave the report a positive review based on their reaction to the screen they were shown in the focus groups. The nurses had mixed awareness (not quantified) of the Alert Section on the Kardex Report, and among those who were aware of it, feedback was generally negative. As a follow-up question, nurses were asked if they prefer the format of alert report section or dashboards for icon alerts. Nurses overwhelmingly preferred the dashboard type of icon alert. Specifically, they liked the dashboard's ability to link to direct action, display information, and convey priorities. Nurses' comments about the Heart Failure Dashboard were mixed with mostly positive feedback at one hospital and mostly negative feedback at the second. In general, nurses disliked Pop-Up Alerts, due to the intrusive nature of the pop-ups; the nurses felt that their use should be extremely selective. Nurses who had encountered the reminder found it irritating and disruptive to their workflow. Nurses also felt that the timing and placement of the pop-ups were annoying and they ought to appear in the pertinent section of the EHR. When asked

about suggestions for future use of pop-ups and guidance for system designers, nurses felt that pop-ups should be used very selectively only for time-sensitive issues related to high level importance measures. They also recommended using them only for one-time events rather than part of a nurse's routine. The generalizability of the research may be limited due to the use of focus groups from the same health system and comments related to some alert components where the nurses had little experience in daily use and reacted in the focus groups.

Multiple studies (Franklin et al., 2017; Sidebottom et al., 2012; Zaydfudim et al., 2009) set out to create useful visualization of data in the form of dashboard and/or icons (alerts) to improve/enhance the nurses' ability to care for patients. Franklin et al., (2017) developed a dashboard to better support clinical decision making in the moment and provide for rapid intervention to improve ED flow. Nurses really want useful icons (alerts) to express what needs to be done now, not tasks in the future or those already completed (Sidebottom, et al. 2012). The VAP dashboard developed by Zaydfudim et al., (2009) was a useful means to graphically display and view compliance with the ventilator bundle compliance to provide greater awareness to nursing staff.

Ease of Use

Hurley et al., (2009) created 17 initial icons representing fall risk and intervention concepts from a prior phase-1 focus group set of interviews using an iterative process. The researchers used a basic content analysis method to interpret the descriptive data from the focus group interviews. Fifty-four study participants, 32 professionals (78% nurses) and 22 nursing assistants, were asked to rate each of the 17 icons using the

established method of content validity index (CVI) and criterion of credibility to understand if the icons were acceptable and could be improved. The CVI is a proportion agreement method, often achieved by a panel of experts who review the proposed tests and determine their relevance in relation to the content domain (Larsson, et al., 2015). Comments were also solicited to assist in enhancing the quantitative rankings. The CVI mean score ratings representing the concept, "out of bed with assist 1" rated lowest at 1.21 (professionals) and 1.18 (nursing assistants) versus the icon designed to represent "history of falling", which was rated high (slightly agree) with scores of 3.15 (professionals) and 3.0 (nursing assistants). The research team selected the icon with the best CVI and ranking by both professional and nursing assistant groups. The illustrator involved with the original icon designs used comments regarding enhancements from the review and analysis to further refine the icons. When results between the nursing assistants and professionals conflicted, icon selection preference was given to the nursing assistant group due to their validated lower literacy level to assure understanding by both groups. The research team agreed to display the simpler text with each icon to improve recognition of the fall risk and assessment concepts. A potential limitation of the study is the preference for icon selection to the assistant group related to their lower literacy level. While the researchers referenced a prior phase of the study had defined/measured literacy level, it may be important to also understand the extent of icon use by both the processionals and nursing assistants. If an icon is well understood and used a majority of the time by the professionals, it may be advantageous to use the professionals' icon preference.

Koch et al., (2012a) conducted a study with 19 ICU nurses from three hospitals: a large academic center (n=10), an academically-affiliated Veterans Administration hospital (n=5), and a large community hospital (n=5) to develop a recommendation for integrated, consolidated information displays to improve ICU nurses' SA. The authors identified three aims. First, identify the frequency of ICU nursing tasks, which was done through systematic observations by two members of the team. Second, identify information needs associated with high-frequency tasks for each level of SA by recognizing gaps or missing information that nurses required to complete a task. Last, create requirements for improved information access to increase nurses' SA during high-frequency tasks. An affinity diagram, i.e., a tool used to organize ideas by relationship to one another, was used to consolidate the large amount of observational data. Opportunities for improvement were recorded on post-it notes and attached to the affinity diagram. Results showed 46 different tasks were performed by ICU nurses, identified at a rate of 23.4 tasks per hour. Performing the most common tasks among nurses requires access to specific information. Unfortunately, this information was often inaccessible, not visible at a distance or located on numerous monitoring devices. The proliferation of devices at patients' bedsides in the ICU does not adequately support nurses' activities on information gathering. The authors found nurses experienced significant challenges in navigating and integrating their information environment. Using the framework of SA, the identification of requirements for integrated displays for nurses could improve the development of better devices. Results from this study were not validated by member

checking and the study is further limited due to a restricted geographical area and a relatively few number of nurses, who were not selected randomly.

Modifying a prototype dashboard designed to summarize and display quality indicators associated with patient risks, Schall et al. (2017) enabled the functionality of the dashboard within an inpatient EHR system for interprofessional rounding. A focus group of nurses, physicians, and quality professionals met to review and discuss the clinical accuracy of the data elements within the EHR functional version of the dashboard. Three pairs of nurses and one physician from unidentified medical-surgical areas volunteered to assist in further refinements, helping to integrate the dashboard directly into the medical center EHR. Participants were asked to perform a series of speak aloud tasks, using both the dashboard and conventional EHR display. These tasks were evaluated to assess potential differences in the amount of time (measured in minutes) necessary to complete a task and the percentage of tasks completed without error between the dashboard and conventional system. Neither measure was evaluated for statistical significance. Results indicated participants completed six of eight tasks faster and with greater accuracy using the dashboard to perform delirium risk, unacceptable pain, urinary catheter >2 days, Barthel Index <50, longer-than-expected lengths of stay, and fall risk. Both task completion and percent accuracy were faster and more easily completed using the conventional EHR for urinary catheter and pressure ulcer. Following the task-based evaluations, participants completed a paper based System Usability Scale (SUS) and Post Study System Usability Questionnaire (PSSUQ). In comparison to the prototype board, the SUS score improved 4.5 points, suggesting the

iterative development of the EHR functional dashboard was beneficial. The overall PSSUQ score of 1.7, suggests the dashboard has good usability. The dashboard is a promising tool for improving speed and accuracy of clinical decision in the complex patient care environment. Several limitations are associated with this study. Typically the participants have the ability to customize personal information displays in the conventional EHR. To assure a consistent platform for each participant, the use of personal information displays were not allowed. This may have slightly decreased participant efficiency compared to typical personal EHR displays. Training for the dashboard system was limited to 10 minutes, which as novices could decrease their performance. Finally the lack of evaluation for statistical significance and the small scope of this study limited the generalizability of the results.

Hurley et al., (2009) established a fall prevention toolkit (FPTK) to assure current and accurate communication of the patient's fall risk status by using icons as a means to simplify and standardize communication across stakeholders. To assure the icons were easy to use and understandable for nurses, an iterative approach was effectively utilized. In an effort to improve the SA of nurses in the ICU, Koch et al., (2012a) developed an integrated display to combat the challenge of combining multiple pieces of disparate clinical information from different locations. The display was easier to use when performing medication tasks and provided context-sensitive decision making. Schall et al., (2017) found the EHR functional dashboard was intuitive and easy to use as compared to the existing EHR, allowing study participants to complete six of eight common nursing tasks faster and with greater accuracy.

Usefulness and Ease of Use

Following a successful implementation of the ED Dashboard, Batley et al. (2011a), examined the design features used in the development of the system and measured which of these features users valued and could therefore have played an important role in the dashboards success. Using a convenience sample of end users, including nurses, the researchers distributed an anonymous self-administered Likert scale self-developed questionnaire. One hundred and eighty eight subjects were invited to participate in the survey. One hundred and seventy five (93%) of those invited completed and returned the surveys. Results from the surveys indicated the ED Dashboard was easy to use (94%), helpful/useful (97%), and functioned better (83%) than other EHR systems used previously. The most valued system attribute were alerts when new test results were ready (98%). Other positively-viewed attributes of the ED Dashboard included use of color, screen layout, and ease of navigation. The level of training required was minimal. Most end users (64%) indicated they had little-to-no training before using the ED Dashboard. Limitations of this study are the claims of increased efficiency gained as a result of the ED Dashboard shared throughout the article. While there may be a relationship, there is no data presented to support those claims.

S. Lee & Huebner (2017) developed and tested four health problem-based dashboards, based on home care practice. Home care nurses in St. Louis County, Missouri were experiencing limitations in their ability to review patient information entered in previous visits. The current EHR tool required nurses to organize pieces of information from multiple screens on their portable laptop. Using a questionnaire, which

included 28 closed-ended questions with a five-point Likert scale and 2 open-ended questions, nurses were asked to give their perception of the clinical dashboards. The survey was sent to three different home care agencies in St. Louis County, Missouri. The three agencies provided a total of 66 eligible nurses. The authors did not explain the distribution of nurses across the three agencies. Fourteen (21%) of the home care nurses completed the survey. In order to collect additional responses to the open-ended questions, the authors selected one home care organization and presented the dashboards at the end of a nursing meeting for 15 minutes. The authors did not explain why only one home care agency was selected or how the one specific agency was chosen. Five nurses provided responses to the open-ended questions. As compared to the nurse's experience with their current portable EHR platform, the home care nurses perceived the newly designed clinical dashboards useful and made suggestions for further enhancements. Limitations of this study included, a restricted geographical area, a small convenience sample based on easy access to the three home care agencies, and the lack of a questionnaire that was tested for validity or reliability. Additionally, the dashboards were not tested directly during the care of patients in the home, only in a simulated scenario.

Eleven public health nurses (PHN), considered expert Omaha System users, were recruited as part of a mixed-method research survey to evaluate prototype visualizations conducted by S. Lee, Kim, & Monsen (2015). The purpose of this study was to visualize how PHN generated Omaha System data and assess the nurses' perceptions regarding the visual validity, helpfulness, usefulness, and importance of the visualization, including interactive functionality. An existing dataset was used to develop two dynamic and

interactive data visualization prototypes true-to-life for a typical client record. To measure the PHNs' perceptions of visualization, the researchers developed a 14-item survey due to the lack of evaluation tools in the literature, using Likert-type ordinal responses, which included visual validity (depicted intended content) of the image, clinical usefulness, importance, and helpfulness. There were five opened-ended questions. The nurses found the time-oriented visualization (TOV) for problems and outcomes had visual validity and agreed the interactive functionality of the TOV was important and useful. The matrix visualization for problems and interventions (MIV) was perceived by the PHNs as having visual validity, but there was a difference in opinion on how the visualization should be displayed. The interactivity functionality of the MIV was deemed important and useful by the PHNs as well. Overall, general support favored the pursuit of using visualizations to summarize and present clinical data in real time for nursing care planning. The generalizability of the research may be limited in part by the small sample size and the static presentation of visualizations versus the actual utilization of an electronic platform to display the visualizations.

K. Lee et al. (2017) created and implemented a medical dashboard system called BESTBoard in all wards, including ICU, emergency room, operation rooms, and delivery rooms, in a tertiary academic hospital to explore process, core designs, functions, usability and feasibility. A group of 10 physicians, 7 charge nurses, and 5 engineers formed a taskforce to assist with developing the dashboard. The taskforce created a user interface design following 6 months of analysis. An additional 3 months was required for hardware configuration and software development. After the BESTBoard was introduced

and installed across the hospital, a survey was administered to all the physicians and nurses using an online tool. The survey was based on the TAM and the Unified Theory of Acceptance and Use of Technology (UTAUT) consisting of 8 main components; performance expectation, effort expectancy, attitude, social influence, facilitating conditions, intention to use, satisfaction, and expectation of work effectiveness. A total of 383 physician and nurses responded to the survey.

Significant associations were found. Voluntary users considered the BESTBoard a good system, had adequate knowledge to use the system, and deemed the BESTBoard useful for team rounds, interdisciplinary team work, and gathering information about the status of hospital rooms. Conversely, elderly users did not find the BESTBoard useful for interdisciplinary teamwork or gathering information about hospital room status. The BESTBoard was not found to be helpful by doctors for research. The authors also performed an analysis of the real usage log, going back two years for the dashboard system to ascertain if the users' intention to use the system affected real usage. The users' positive intentions to use the BESTBoard did positively influence the real usage of the system. Overall, users identified several key features, including the ease of the search method, the ease of capturing core health information, the ease with which healthcare professional can check a patient's condition, the availability of advanced user experience, and the use of a large display to support utilization.

In a study conducted by Tan et al., (2013), the authors gathered and evaluated end-user feedback regarding factors that influence user satisfaction of an iterative electronic dashboard to improve the visibility of vital patient data associated with a

current computerized physician order entry (CPOE) system. The dashboard was primarily designed to alert nurses of urgent "STAT" orders, abnormal lab or radiology results, and infection control issues. The dashboard had additional operational functions that included discharge process tracking and radiology scheduler with pre-scan checklist. The dashboard displayed several icons/flags with different color statuses to indicate criticality and alert key patient issues and not to replace CPOE functions. Using a mixed-methods approach, Tan et al., (2013) recruited nurses from five pilot wards (four medical, and one multi-disciplinary ward with both medical and surgical patients) and the radiology department. The nurses all had been primary users of the new dashboard and had also used the CPOE system for at least three months. Nurses completed a validated questionnaire (12 statements) and had the opportunity to provide further feedback through two open-ended questions. One hundred twenty-two nurses out of a total of 170 eligible staff from the five pilot wards responded to the survey, reaching a total response rate of 72%. Sixteen survey forms had to be discarded due to lack of completeness, resulting in 106 usable surveys. The overall usage of the system was high with 86% of nurses using it every shift. Twenty-five (24%) nurses claimed that they would look at the dashboard once every hour, while 9 (8%) would look once every 30 minutes. This meant that 32% (24% + 8%) or 1 in 3 nurses would look at the dashboard at least once every hour. The nurses were generally satisfied with the dashboard, with a mean user satisfaction score of 3.6 out of a scale of 5. The nurses gave high scores to two statements; information from the dashboard was relevant (3.93/5); and accurate (3.81/5). The statement, “The Andon Board was easy to use” scored 3.89 out of 5. Conversely, the

nurses did encounter some issues in adopting with the new dashboard system. Nurses shared that the system froze occasionally, and the interactive touch screens were too sensitive. The nurses then suggested improvements in the display format and as well as suggested new locations for the dashboards to optimize visibility. Five system attributes were strongly and positively associated with user satisfaction, as determined by a correlation analysis, and were related to two main constructs: perceived impact on work efficiency (Q3, saves me time [0.70]; Q4, enable me to accomplish tasks more quickly [0.68]; Q5, enhance my efficiency in the job [0.70]) and perceived impact on care quality (Q6, helps me improve patient safety [0.62]; Q7 helps me to care better for patients [0.63]). From the qualitative feedback, nurses indicated they appreciated the ability to improve awareness of critical patient issues without the need to navigate the CPOE system. The full generalizability of this study across other hospitals and healthcare systems needs careful consideration. In many post-implementation studies, several months pass after a system implementation to allow for stabilization and comfort of the users. This study was conducted within one month of being live on the dashboard, in part, to solicit feedback from the nurses to learn and fix issues prior to full implementation.

Cognitive Load and Usefulness

Using a counter-balance, repeated measures, study design, Koch et al., (2012b) conducted a study to measure whether nurses' user-interaction satisfaction would increase or if mental workload would decrease when using an integrated information display, compared to displays used in a traditional setting. Twelve burn trauma ICU

nurses evaluated each type of display, with the median duration being 23 minutes each, over two study sessions on two consecutive nights. The Questionnaire for Use Interaction Satisfaction (QUIS) and two free-text questions were used to measure the nurses' user-interaction satisfaction, while the NASA TLX questionnaire was used to measure mental workload. Each display viewed by the nurses was used to identify information about medication management, patient awareness, and team communication. Results of the satisfaction items from the QUIS were summed across dimensions, revealing a statistical improvement with the integrated display among the nurses. The mean workload score from the NASA TLX was calculated with equal weights for each of the scale's six dimensions. Two of the NASA TLX dimensions, effort and frustration, were statistically significant using the integrated display. The results show the potential benefit of an integrated information display to lower mental workload, reduce errors, and improve treatment times. The generalizability of the research may be limited in part to the use of paper prototypes vs. the electronic display, the small sample size, and the use of a single specific setting.

Summary of Findings

This critical review of the literature affords a limited number of studies that provide examples of nurses using icons (visual representation) and/or digital dashboards to fully utilize and manage clinical data. A common theme in all the studies was the day-to-day challenges nurses encounter navigating and integrating all the streams of data and information from multiple sources regarding their patients. The studies demonstrate

efforts to improve the usefulness and the ease in which clinical data can be maximized at the point of care, while also lessening the cognitive burden. There is evidence that the use of integrated dashboards with data representation by icons does provide advantages to the nurse in healthcare, especially with the rapid advancement of EHR and monitor technology. Other opportunities will continue with the associated multitude of clinical data that will need efficient methods for nurses to assimilate and manage during the provision of patient care.

All twelve of the studies in this review provided findings that support the use of icons (visual representation) and/or digital dashboards to improve a nurse's ability to synthesize significant amounts of clinical data. Two of the studies (Hurley et al., 2009; Sidebottom et al., 2012) focused on end user feedback, rating/describing icons on their strength and recognition. In the Hurley et al. (2009) study, the researchers built the icons which were rated and ranked most positively among the end users. Sidebottom et al., (2012) received feedback on the icon (alert) usefulness in the workflow. Ten of the studies (Batley et al., 2011a; Franklin et al., 2017; Koch et al., 2012a; Koch et al., 2012b; K. Lee et al., 2017; S. Lee, Kim, & Monsen, 2015; S. Lee & Huebner, 2017; Schall et al., 2017; Sidebottom et al., 2012; Zaydfudim et al., 2009b) established the importance of using an integrated display or dashboard to sufficiently allow the nurses to visualize clinical data more efficiently or in an actionable manner. Nurses want to see what needs to be done or is relevant now for the patient, not clinical data that is in the distant future or has already been completed.

Limitations and Opportunities for Future Research

Research in this domain is limited by lack of experimental studies and use of small, mostly homogenous samples, which may decrease the generalizability. A limited number of studies regarding the types, use, and clinical data utilization and management of icon-based electronic clinical dashboards for nurses exist and the majority are cross-sectional in design. Cross-sectional designs provide only information at a fixed point in time, thus no information can be ascertained on causality. While a survey tool was used as a data collection method in several studies, three of the surveys (Batley et al., 2011; S. Lee & Huebner, 2017; Tan et al., 2013) lacked reference to any formal type of validity or reliability measure. Lack of testing of the survey questionnaire can lead to study design bias, because researchers fail to identify validity (accuracy) and precision (reliability) problems when the survey instrument is not validated. These attributes ensure results of the study are replicable. In addition, four studies (Batley et al., 2011; S. Lee & Huebner, 2017; S. Lee, Kim, & Monsen, 2015; Schall et al., 2017), although quantitative, did not contain a formal statistical evaluation for significance. There is a need for more quality studies to be published regarding what is known about nurse clinical data consumption and management through the use of icons and digital dashboards.

Future research should focus on understanding how icons and dashboards can improve nurses' willingness to use, perception of increased value, and lessen the workload burden as compared to an existing EHR system. Actively engaging nurses upfront in study design and rigorous research methodologies so that study findings are

generalizable to larger populations and replicable will advance scientific knowledge. Future researchers need to use larger and more diverse samples to ensure study findings are transferable and identify emerging trends involving the types, use, and clinical data consumption and management through the use of icons (visual representation) and digital dashboards.

The use of icons and dashboards are generally created for a specific population of patients (e.g., ICU, Public Health, ED) and/or an identified function/need (e.g., CPOE, Falls, VAP). Future research should evaluate the impact of integrated data with other populations, in other settings, to understand what core clinical data can be shared across this continuum of care and where tailoring can be used to meet specialty needs.

More evidence is also needed to understand and refine the impact of data visualization through icons and dashboard on the effect of decision making for the nurse during the provision of care. Simply producing a number and variety of flags, alerts, color changes, and other functions within a visual display may be relatively straight forward, but could be of little value. Future research is needed to understand and mitigate cognitive overload to find a balance point for nurses to appreciate and trust that the icons and dashboards are providing reliable and timely information that benefit patient care.

Lastly, future research is needed to help determine how the use of icons and dashboards impact nursing workflow efficiency and quality. Will there be a reduction in the time needed to perform clinical review of a patient's health record? Does the aggregation and display of disparate EHR data across multiple systems pulled together

into a single view or alert, improve the timeliness and outcomes of patient care? As the complexity of monitoring equipment and the availability of discrete data grows almost exponentially, nurses need new and improved methods of managing clinical information. Those new methods of visualization must be proven and trusted partners for nursing to fully embrace.

Conclusion

The use of data visualization tools in the form of icons and/or dashboards specific to nursing workflows is sparsely represented in the literature. In addition, there is very limited understanding how or if icons and dashboard provide advantages over core EHR capabilities. This literature review describes an analysis and synthesis of factors and issues associated with the clinical data utilization and management of icon-based electronic clinical dashboards. Based on the analysis, the researcher proposed a conceptual model that deliberately seeks to understand how the concepts of usefulness, ease of use, and cognitive load together impact the nurse's intention to use the icons and/or dashboards. The use of Technology Assessment Model (TAM), NASA TLX, and external factors allows for a comprehensive approach in understanding facilitators and barriers for nurses to use data visualization tools and the evaluation of future data visualization structures. Nurse input and research creates feedback loops to monitor gaps, identify opportunities, and modify data visualization tools in the form of icons and dashboards toward a more user centric model. The researcher believes assuring icons and dashboards are easy to use, provide value, and have a low cognitive burden will positively influence nurses to trust and fully utilize the EHR environment.

Chapter 3: Methods

Study Design

A descriptive, comparative mixed methods design was used to address the aims of this study using a secondary dataset.

Setting. The setting for the research study was three patient care units at a large Midwestern academic medical center. The three units represent a cross-section of specialties in the general care setting, see table 2.

Table 2

Unit Descriptions

Unit	Bed Quantity	Specialty Description
Unit A	19	General Surgery
Unit B	44	Medical, Surgical, Oncology, General Care Pediatrics
Unit C	36	General Medical

Implementation of the INFUZE board technology included utilization of computer screen monitors in non-patient areas. These monitors are "view only" with no direct tactile interaction by nursing staff. The screens provide the nurse with a quick visual reference for clinical changes and updates. Staff can interact with the INFUZE board by logging into the system via an EED (Electronic Environment Device) computer or other electronic device with Internet access such as the iPhone, iPad, or iPod Touch. Through the log-in function detailed clinical data for clinical decisions and prioritization

of cares is obtained by hovering over the desired icon. The software interfaces to several core EHR systems, aggregating desired data, and displaying in a comprehensive way to the user.

Subjects. This study analyzed adult, RNs, who work a scheduled full time equivalent (FTE) of at least 0.5 on one of three in-patient units regardless of the shift rotation. The FTE threshold was chosen to assure an adequate amount of exposure to ICS and INFUZE. All RNs meeting the FTE requirement on these three units were included as part of the study without exclusion based on ethnicity or race; however they must be English speaking. Pregnant women were eligible for participation because no risk was identified for their exclusion. Individuals were assured that their participation in the survey was voluntary and anonymous; completion of the surveys signified consent.

Data Set. After approval from the Institutional Review Board (IRB), a limited secondary dataset from the INFUZE nursing satisfaction evaluation was created. The dataset originated from a large Midwestern academic medical center and included data from two questionnaires administered September 19, 2012 to January 31, 2013. An estimated 131 nurses completed the ICS questionnaire and 85 nurses completed the INFUZE questionnaire. Additionally, three voluntary focus groups were conducted with a total of 13 participants.

The initial questionnaire, or questionnaire 1, was conducted prior to the implementation of INFUZE and focused on ICS. The follow up questionnaire, or questionnaire 2, focused on INFUZE 8-12 weeks after implementation. Lastly, data from nurses who completed both the ICS and INFUZE surveys were randomly invited to

participate in three small focus groups. The results from questionnaire 1 were compared with the results from questionnaire 2 to evaluate the nurses' perceptions of the availability of patient data between the two systems. The focus group data provided participant perspectives and opinions about the experience and usefulness of the INFUZE Board. Focus groups are an effective means of gathering data about shared experiences and are especially useful for the evaluation of products and tools (Krueger & Casey, 2014).

Questionnaires. The original questionnaires collected information from study participants related to demographics, PEU, PU, and the TLX (Appendix A and B). The focus group discussion used an interview guide (Appendix C) to assist with consistency across the 3 separate focus groups conducted.

Demographic information included five questions: unit, age, gender, education, and nursing experience. Nurses provided the last five digits of their phone number on questionnaires to compare similarities and differences. Four questions focused on the individual's comfort with technology, computers, and cell/smart phones.

The PEU and PU questions were modified from Hyun, Johnson, Stetson, & Bakken's (2009) original seventeen questions using a five-point Likert scale. The scale ranges from 1 (strongly agree) to 5 (strongly disagree). The additional questions added to this study, remain true to the core intent of Hyun et al. This study adopted the same 5-point Likert scale and extended question number one to assess different functions of the systems relative to "easy to use" for PEU and "quality of work I do" for PU. Both of these key concepts are associated with TAM, a component of the conceptual framework.

The total number of questions, while remaining core to the original ten for each TAM concept was expanded to 23 for PEU and 23 for PU, with the additional functions. If the nurse also performed the role of charge nurse on occasion, they received an additional 14 questions for PEU and 14 for PU based on the same method used for the RN. Questions were expanded in order to measure multiple variables independently and between the roles of staff nurse and charge nurse within ICS and the INFUZE systems. Research supports convergent, discriminant, and factorial validity and internal consistency (Cronbach's alpha reliability = 0.94 for PEU and 0.98 for PU) of the questionnaire (Davis, 1989).

Hart and Staveland's (1998) TLX method assesses workload on six 7-point scales. Increments of high, medium, and low estimates for each point result in 21 gradations on the scale. This instrument contributes to the workload concept in the conceptual framework, providing a measurement of PEU.

Nurses who completed both the ICS and INFUZE surveys were eligible to participate in one 3 focus groups. Up to ten nurses were randomly invited to attend one of the focus groups. An interview guide with open ended and semi structured questions was used by an experienced qualitative nurse researcher. Examples of probes that were used to guide the interview are provided in Appendix B. Following the principles of focus group interviewing (Krueger & Casey, 2009), the moderator used the interview guide to ensure the discussion addresses the topic of interest with additional probes used as needed to clarify participant responses and/or elicit more detailed responses. Findings were shared with a small subset of group participants for validation of the interpretation.

Data Pre-processing. The dataset was transferred to a secure environment for data processing, management, and analysis. This process was accomplished following the steps described below and by adhering to ethical issues for the privacy and security (Dunn, Arslanian-Engoren, DeKoekkoek, Jadack, & Scott, 2015).

1. Data quality: any duplicate records was deleted. Data was compared for inclusion and exclusion criteria.
2. Data was reviewed a second time for usefulness in answering the research question and for any additional PHI that may not be de-identified before data transfer.
3. Further review of the data was performed with the aim of determining data quality, such as data collection errors, outliers, missing values, inconsistent values, and duplicates.

Analytic Plan. Secondary data from the two questionnaires was analyzed to evaluate the usefulness, ease of use, and cognitive workload for nurses in retrieving clinical patient care data from the ICS and the INFUZE board icon interface system. The PEU and UE via the TAM, were measured using a five-point Likert scale. Cognitive workload (NASA TLX) was measured using a seven-point Likert scale. Comparisons of the scales, between ICS and the INFUZE board, were evaluated using paired t-tests and Wilcoxon signed-rank tests to account for the paired nature of the data (i.e., an ICS and INFUZE questionnaire completed by the same nurse). Associations between demographic features such as age and gender with differences in the paired scales (INFUZE minus ICS) using univariate and multivariable linear regression were also

determined. All tests are two-sided with p-values of <0.05 considered statistically significant.

To complement and provide further insight related to the quantitative data, the focus groups secondary data was analyzed using constant comparative and content analysis (Krippendorff, 2004; Krueger & Casey, 2014). The established patterns and relationships in the data were reviewed.

To address the study aims, continuous features were summarized with means, standard deviations (SDs), medians, ranges, and interquartile ranges (IQRs); categorical features were summarized with frequency counts and percentages. Comparisons of individual items, total scores, and mean scores between ICS and the INFUZE board were evaluated using Wilcoxon signed rank tests for those participants who completed both a pre and post questionnaire. Associations of demographic features with differences between ICS and the INFUZE board were evaluated using Kruskal-Wallis, Wilcoxon rank sum, and Spearman rank correlation coefficients. Statistical analyses were performed using the SAS software package (SAS Institute, Cary, NC). All tests were two-sided with p-values of <0.05 considered statistically significant. To complement and provide further insight, focus group data was also included in the dataset and analyzed using constant comparative and content analysis.

Data Analysis

The questionnaires included 23 items to evaluate PEU of ICS and the INFUZE board. The response to each item was scored as 1=strongly agree, 2=agree, 3=neutral, 4=disagree, and 5=strongly disagree. A total ease of use score was calculated as the sum

of the 23 items after reverse-scoring items 17, 19, 20, and 22. As such, total ease of use scores could range from 23 to 115. Lower scores indicated that the ICS/INFUZE board was easier to use. [The items in the 2009 article by Hyun et al in Journal of Biomedical Informatics were scored as 0=strongly disagree, 1=disagree, 2=neutral, 3=agree, and 4=strongly agree. Therefore, the total scores in the current study cannot be directly compared to the total scores reported by Hyun et al.] A mean ease of use score was calculated as the mean of the 23 items. Total and mean scores were only calculated for respondents who answered all 23 items.

The questionnaires also included 23 items to evaluate PU of ICS and the INFUZE board. The response to each item was scored as 1=strongly agree, 2=agree, 3=neutral, 4=disagree, and 5=strongly disagree. A total usefulness score was calculated as the sum of the 23 items and a mean usefulness score was calculated as the mean of the 23 items. Total usefulness scores could range from 23 to 115, with lower scores indicating that the ICS/INFUZE board was more useful. Total and mean scores were only calculated for respondents who answered all 23 items.

Measured PEU and PU scores were also calculated for the subset of nurses who performed the role of charge nurse on their nursing unit. These scores were made up of 15 items related to ease of use and 16 items related to usefulness. The ease of use score for charge nurses was calculated after reverse-scoring items 55, 57, 58, and 60. Total ease of use scores for charge nurses could range from 15 to 75 and total usefulness scores for charge nurses could range from 16 to 80.

Cognitive workload was measured using 6 items from the NASA TLX. The response to each item was scored from 1 to 7 with 1=not at all and 7=extreme. As with the ease of use and usefulness scores, total and mean cognitive workload scores were calculated as the sum and mean of the 6 NASA TLX items, respectively. Total cognitive workload scores could range from 6 to 42, with lower scores indicating reduced cognitive workload.

Continuous features were summarized with means, standard deviations (SDs), medians, ranges, and interquartile ranges (IQRs); categorical features were summarized with frequency counts and percentages. Comparisons of individual items, total scores, and mean scores between ICS and the INFUZE board were evaluated using Wilcoxon signed rank tests for those participants who completed both a pre and post questionnaire. Associations of demographic features with differences between ICS and the INFUZE board were evaluated using Kruskal-Wallis, Wilcoxon rank sum, and Spearman rank correlation coefficients. Statistical analyses were performed using the SAS software package (SAS Institute, Cary, NC). All tests were two-sided and p-values <0.05 were considered statistically significant.

Ethical Considerations

The research project was submitted and approved through the University of Minnesota, following ethical standards for human protection and data sharing. The dataset was de-identified. It was transferred note protocol. In the original study, the informed consent included there ethical principles: human dignity, beneficence, and justice. The nurses were provided full disclosures of the study's purposes and copies of

their rights as human subjects. Participation in the study was voluntary and the nurses could withdraw from the study at any time without penalty. The information sheet, consent form, and questionnaires were provided to the nurses after the purpose of the research study was explained and confidentiality was reassured.

There are ethical concerns relative to the use of technology and specifically electronic health tools. As more and more technology is used to care for patients, more and more barriers are created between clinicians and their patients. Ruiter, Liaschenko, & Angus, (2016) provide five potential consequences of the EHR. The first is that the EHR portrays each patient as a composite of risk factors and interventions, which normalizes and routinizes the patient, leading to a de-emphasis of the experiential or practice-based knowledge for the nurse. Second, patients may become less willing to share pertinent information for fear it will be utilized and accessed as a commodity of data points useful to interested parties for many purposes. Third, the need by the institutions to use discrete data for the surveillance of nurses and patients has shifted the power from the nurse to the administrators of health care. Fourth, the work of documentation has increased for nurses, as they are no longer solely responsible for the care of patients, but documentation to satisfy data for the institutions priorities. Lastly, the computer and other technologies in the patient room have changed the relationship between the nurse and patient. Nurses often look at screens while asking questions rather than the patients themselves. As the use of technology and electronic health tools grows, it is imperative nurses understand the ethical implications to patient care.

This study considered the five potential consequence and how each could become a barrier with the use of INFUZE. While clinical data displayed on the INFUZE board relates to specific patients, the board provides specific and relative data requiring timely action. Nurses need a strong practice base to critically evaluate and appropriately take action to care for the patient. The INFUZE board is an aggregator of data, allowing for the coalescence of disparate, but specific data into a single view. INFUZE is not a documentation system or a repository. INFUZE is a clinical application with access only granted for those caring directly for patients. The board does not have the capability to provide surveillance of nurses or others. The INFUZE board is only placed in nursing stations, which avoids the board getting between the patient and nurse.

Conclusion

This study compared the nurses' PU, PEU, and workload burden between the ICS and the icon-based electronic clinical dashboard system, INFUZE. The research approach used an extended conceptual framework, utilization the TAM and TLX models and the inclusion of external variable, of support resources, experience, demographics, and relevance to task.

Chapter 4: Results

This chapter addresses the four study aims: (1) determine nurses' PU of ICS, compared to INFUZE, to retrieve pertinent information relative to patient care and nursing unit operation; (2) determine nurses' PEU of ICS, compared to INFUZE, to retrieve pertinent information relative to patient care and nursing unit operation; (3) determine nurses' perception of workload, using ICS, compared to INFUZE, to retrieve pertinent information relative to patient care and nursing unit operation; and (4) determine nurses' perceptions of how the INFUZE Board facilitated or hindered their intention to use the tool through focus group interviews. To address the study aims, the researcher used standard inferential and descriptive statistics.

Demographic Characteristics

The following section presents demographic characteristics of the sample population. The average age of the 63 nurses was 33.6 years (SD=10.5); the nurses used personal computers an average of 11.5 hours per week (SD=7.6). Most nurses were female, BSN-prepared, and comfortable or very comfortable using technology. The summary of the characteristics for each attribute is displayed in Table 3.

Table 3

Frequencies and Percentages of Demographical Data (N = 63)

Technology Use	*n (%)*
Web Browsing (cell/smart phone)	
No	14 (22.2%)
Yes	49 (77.8%)
E-mail (cell/smart phone)	
No	15 (23.8%)
Yes	48 (76.2%)
Photos (cell/smart phone)	
No	11 (17.5%)
Yes	52 (82.5%)
Social Networking (cell/smart phone)	
No	19 (30.2%)
Yes	44 (69.8%)
Music (cell/smart phone)	
No	23 (36.5%)
Yes	40 (63.5%)

For PEU and PU, ICS was favored over INFUZE ($p \leq .001$ for all). For workload, INFUZE was favored over ICS ($p < .001$) (Table 4).

Table 4

Descriptive statistics for difference among all nurses comparing ICS and INFUZE.

Item	Mean ICS	Mean INFUZE	Mean difference	*t*	*df*	*p*
AVEPEU	2.46	2.71	0.25	-4.07	210	<.001
AVEPU	2.53	3.46	<0.93	-8.07	201	<.001
AVENASA	3.44	2.72	-0.73	6.32	186	<.001
SUMPEU	57.55	63.95	6.4	-3.43	214	0.001
SUMPU	50.4	72.47	22.07	3.85	214	<.001
SUMNASA	18.15	14.01	-4.14	3.85	214	<.001

Note. AVEPEU = average perceived ease of use; AVEPU = average perceived usefulness; average National Aeronautics and Space Administration; SUMPEU = summation perceived ease of use; SUMPU = summation perceived usefulness; SUMNASA = summation National Aeronautics and Space Administration.

Ranges of the sums of TAM factors were at the lower end of the total possible scores, with a narrower range for ICS than for INFUZE. Table 5 shows the percentages of the maximum scores for all variables.

Table 5

Percentages of Maximum Scores for Factors of the TAM.

			ICS		INFUZE	
TAM Factors	MinPS	MaxPS	Mean	% MaxPS	Mean	% MaxPS
TLX	6	42	18.15	43.21	14.01	33.36
PEU	23	115	55.75	48.48	63.95	55.61
PU	23	115	50.4	43.83	72.49	63.03

Note. TAM = technology assessment model; PEU = perceived ease of use; PU = perceived usefulness; TLX = task load index; PS = possible score; Min = minimum; Max = maximum; % = percent.

Aim 1: Determine nurses' PEU of ICS as compared to INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit

The analysis for Aim 1, Determine nurses' PEU of ICS as compared to INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit, was accomplished using independent samples *t*-tests in SPSS version 21. Twelve of 23 items differed significantly: 10 favored ICS over INFUZE (demographics, chief complaint, admission medical diagnosis, significant history, service identification, radiology reports, vital signs, new orders, laboratory results, care provider, b.i.d. assessment, and effort to use ICS) and 2 items favored INFUZE over ICS (isolation status and primary nurse). Table 6 shows average PEU by question for ICS and INFUZE (lower scores are better).

Table 6

PEU questionnaire items, descriptive statistics for difference among all nurses comparing ICS and INFUZE.

Item	Mean ICS	Mean INFUZE	Mean Difference	*T*	*df*	*p*
PEU_1	2.16	2.20	0.04	-0.34	210	0.732
PEU_2	2.14	2.48	0.34	-2.88	210	0.004
PEU_3	2.45	2.76	0.32	-2.53	210	0.012
PEU_4	2.2	2.8	0.59	-4.79	210	<.001
PEU_5	2.39	3.07	0.68	-4.99	210	<.001
PEU_6	2.13	1.82	-0.31	2.44	210	0.015
PEU_7	1.9	1.74	-0.16	1.38	210	0.169
PEU_8	2.32	2.92	0.6	-5.05	210	<.001
PEU_9	1.76	2.63	0.87	-7.33	210	<.001
PEU_10	2.28	3.3	1.02	-7.44	207	<.001
PEU_11	2.03	2.81	0.78	-6.15	210	<.001
PEU_12	2.34	2.37	0.03	-0.26	210	0.799
PEU_13	1.91	2.52	0.62	-4.68	210	<.001
PEU_14	2.4	2.55	0.15	-1.03	210	0.304

(continued)

Item	Mean ICS	Mean INFUZE	Mean Difference	*T*	*df*	*p*
PEU_15	3.37	2.2	-1.16	7.58	209	<.001
PEU_16	2.4	2.17	-0.23	1.83	209	0.069
PEU_17	3.13	3.18	0.05	-0.34	209	0.732
PEU_18	2.67	2.76	0.09	-0.67	209	0.503
PEU_19	3.21	3.22	0.01	-0.05	209	0.964
PEU_20	3.3	3.53	0.23	-1.86	209	0.064
PEU_21	2.41	2.54	0.14	-1.13	209	0.262
PEU_22	2.94	3.52	0.58	-4.59	209	<.001
PEU_23	2.51	2.48	-0.03	0.2	209	0.842

Note. PEU = perceived ease of use; ICS = integrated clinical system.

Aim 2: Determine nurses' PU of ICS as compared to INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit

The analysis for Aim 2, Determine nurses' PU of ICS as compared to INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit, was accomplished using independent samples *t*-tests in SPSS version 21. All 23 items favored ICS over INFUZE ($p \leq .001$). Table 7 shows average PU by question for ICS and INFUZE (lower scores are better).

Table 7

PU questionnaire items, descriptive statistics for difference among all nurses comparing ICS and INFUZE.

Item	Mean ICS	Mean INFUZE	Mean Difference	*t*	*df*	*p*
PU_24	2.75	3.58	0.83	-6.35	201	<.001
PU_25	2.98	3.62	0.63	-5.28	201	<.001
PU_26	2.66	3.51	0.85	-6.4	200	<.001
PU_27	2.42	3.56	1.14	-8.54	199	<.001
PU_28	2.35	3.59	1.24	-9.27	199	<.001
PU_29	2.46	2.96	0.5	-3.29	199	0.001
PU_30	2.27	2.91	0.65	-4.45	199	<.001
PU_31	2.59	3.58	0.99	-7.8	199	<.001
PU_32	2.15	3.37	1.22	-9.29	199	<.001
PU_33	2.36	3.49	1.14	-8.4	199	<.001
PU_34	2.25	3.43	1.18	-9.05	199	<.001
PU_35	2.6	3.22	0.62	-4.35	199	<.001
PU_36	2.26	3.52	1.26	-9.74	199	<.001

(continued)

Item	Mean ICS	Mean INFUZE	Mean Difference	*t*	*df*	*p*
PU_37	2.46	3.31	0.85	-6.17	199	<.001
PU_38	2.51	3.52	1.01	-7.42	199	<.001
PU_39	2.77	3.6	0.84	-5.72	199	<.001
PU_40	2.33	3.32	1	-7.02	199	<.001
PU_41	2.68	3.59	0.91	-6.38	199	<.001
PU_42	2.62	3.59	0.98	-7.06	199	<.001
PU_43	2.78	3.77	0.98	-6.97	199	<.001
PU_44	2.59	3.62	1.03	-7.22	199	<.001
PU_45	2.62	3.58	0.96	-6.72	199	<.001
PU_46	2.25	3.38	1.13	-8.16	199	<.001

Note. PU = perceived usefulness; ICS = integrated clinical system.

Aim 3: Determine nurses' perception of workload, using ICS as compared to INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit

The analysis for Aim 3: Determine nurses' perception of workload, using ICS as compared to INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit, was accomplished using independent samples *t*-tests in SPSS version 21. All 6 items favored INFUZE over ICS; five items significantly ($p \leq .003$).

The exception was performance, which while lower, was not significantly different. Table 8 shows average workload by question for ICS and INFUZE (lower scores are better).

Table 8

TLX questionnaire items, descriptive statistics for difference among all nurses comparing ICS and INFUZE.

Item	Mean ICS	Mean INFUZE	Mean Difference	*t*	*df*	*p*
nasa_effo	3.63	2.68	-0.95	4.78	186	<.001
nasa_frus	3.79	3.03	-0.76	3.08	186	0.002
nasa_ment	3.38	2.3	-1.08	5.49	186	<.001
nasa_perf	4.7	4.55	-0.15	0.66	186	0.51
nasa_phys	1.98	1.51	-0.48	3.02	186	0.003
nasa_temp	3.18	2.25	-0.94	4.42	186	<.001

Note. nasa = National Aeronautics and Space Administration; effo = effort; frus = frustration; ment = mental; perf = performance; phys = physicial; temp = temporal.

Aim 4: Determine nurses' perceptions of how the INFUZE Board facilitated or hindered their intention to use the tool.

Focus Group Findings: INFUZE Board

At the beginning of the focus group, participants were each asked to assign a letter grade to the INFUZE Board. Scores ranged from a B to D (Figure 3). The majority of scores were C or lower, no scores of A or F were given. Despite the low scores,

participants expressed optimism in some of their comments below that the INFUZE Board could be improved upon and had potential to be a useful tool for nurses.

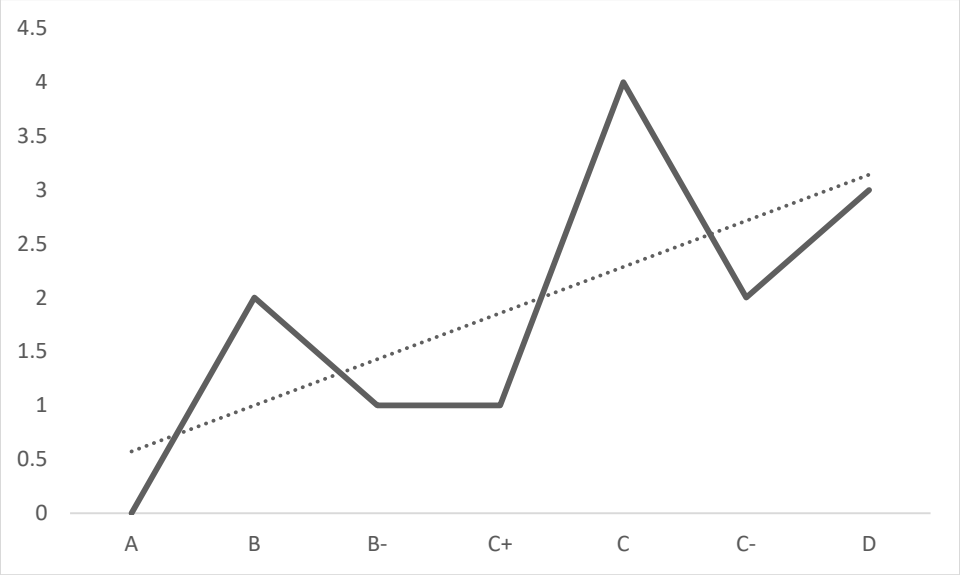

Figure 3. *Focus Group Participant Grades for INFUZE*

Participants identified several concepts quoted below related to the tool's usefulness for clinical support. The tool's potential to help in decision support, participant's described the impact of the INFUZE Board in relation to workflow. They found the INFUZE Board to require a learning curve in order to incorporate its use into daily workflow routines and was described as 'Just *another thing to do'*. One aspect of this theme was the perceived *lack of integration of the INFUZE Board with other electronic tools* including the EHR. *Claiming patients* was a frequent source of frustration with the INFUZE Board and added to the sense of burden in that nurses' are required to manually 'claim' their patients in the INFUZE Board rather than this being a transparent process

related to assigned patient workload. Alerts were also considered just another thing to do because of the nurses' inability to tailor alert parameters to the patient. They voiced that the pre-set alert parameters were often of limited usefulness because they either did not provide enough information requiring deeper looking into the EHR or were for aspects of care not of importance to a particular patient.

1. 'Just another thing to do'
    a. The usefulness of the INFUZE Board as a clinical tool is not yet appreciated. Thus, it is not integrated into daily workflow, and a sense that it is "just another thing to do."

> *...feeling like it's a useful tool and it's something that you can easily accomplish as opposed to being a big obtrusive burden in your workflow.*
>
> *It's kinda like what's the tool going to do for us now, and what do we have to do for the toolbut it also seems like it's another system for us to open up. Um, and you've gotta remember to open it up in the morning, you know? We have the one screen on each hallway, but lots of times, where I'm sitting, it's at my back. So in order for me to be—for it to be user friendly, I've gotta remember to open it up on my computer screen and it's, you know, when you're starting your day, it's like one more thing to remember. Um, I work part-time, too, so it's not part of my habit yet ...*
>
> *So, okay but you know it, it's not helping, helpful to us in our daily work as a staff nurse. Um, as a charge nurse I only utilize it for, um, to look at it to see which rooms are cleaned. That is something that I really utilize.*
>
> *You know I think if we integrated it more into the practice, then it would be more of an applicable thing. But now it's we still have to go to the assignment sheet to get our assignments, ultimately. So why should we mess around with the INFUZE Board?*

b. “integration with other electronic systems”

Participants felt that the INFUZE Board met its intent to provide snapshot overview of the patient but the lack of integration with existing electronic tools added to the burden of using it efficiently. In order to access the information required to make decisions, the clinical documentation system (ICS) needed to be accessed so nurses felt the INFUZE Board served as a sort of ‘middle-man’ that got in the way of quick navigation.

> *It’s just m-, most of the work that we’re doing is, like, you’re doing it in ICS. So to have, like, a separate window with the INFUZE Board to look for labs or vitals or something like that*
>
> *You really can’t have two windows open at the same time and why would you go over here when it has bits and pieces of information and ICS has everything.*
>
> *And I think that the, the INFUZE Board is an alert system. I think that’s what we would only utilize it for, like, if we had a lab or a vital or something. But then we still—like [name] said, you still have to go into ICS and look at all your lab values and say was it the gluco-, okay we had a glucose off, we had a hemoglobin off or platelets are low. You know so it’s like okay it tells me the labs are back and there’s an alert, but I still have to do another step.*
>
> *it would be nice if it was more integrated or somehow interface—no, I don’t wanna say interface, because we pull—the information on the INFUZE Board is pulled from the ICS system. But it just seems like the systems are completely different. You know, I mean, it’s—they seem like they’re two different animals [laughter]. You know, and if—I think it’d be more user friendly if somehow it was if there was a way that we could actually chart off the INFUZE Board, or something…*
>
> *There’s not—there’s not a two-way street there. I mean, it—it pulls the info—the information is in ICS, it’s just that the INFUZE Board makes it easier to find. But yet, there’s no way to make it use-to kind of go back and do that*

> *deeper dive in ICS easily from the INFUZE Board…I think it would—people would use it more if we could go back and forth. But I don't know if that's a possibility. So we need a two-way street instead of a dead end.*
>
> *No, I think that that's good. I think that that's good, 'cuz if you—if you hovered over it and you saw the x-ray—you see the x-ray report, and then, if you could click and actually take you to Q reads so you can see the x-ray, or sometimes, you—you don't see the full report. You can see the full thing, you know, I think that would be really helpful.*
>
> *To chart it, I think that would eliminate probably three clicks and three thinking processes. It would just send you right there. And so then, that's value added because it streamlines and makes your work easier.*

In addition to limited integration with other clinical systems, some nurse participants did not feel the INFUZE Board added value because the information provided is already available elsewhere. Participants suggested that although the clinical documentation system is challenging to navigate and has its own set of limitations, they are used to and able to navigate that existing system to find the needed information.

> *And I think, the other thing that's really frustrating to me is [nurse managers say] oh well we like going to the INFUZE Board and seeing who had these patients at 2:00 yesterday. And I'm like well there's an assignment sheet that does that too. So, like, I feel like everything on the INFUZE Board is replicated somewhere else.*

c. "Claiming patients"

Claiming patients (officially assigning a patient to a nurse) in the INFUZE Board was an opportunity specifically identified by participants as an opportunity for integration across electronic applications.

> *like claiming our patients, like if there was an automatic way for that to happen because I think, um, a lotta the nurses know as we come on it, it—we see it as, you know, one more thing to do to claim your patients, and you have to, you know, it's kinda cumbersome like they were saying. Like you have to sometimes click on it*

like four times in—in order for your folder to pop up. So just like if there was a way when you came on and your photo was automatically up there based on the electronic assignment tool, I think that would

It should be tied in with the electronic assignment. Once that gets figured out, when the charge nurse has assigned it through the electronic assignment, it should automatically claim those patients starting at 7:00 a.m. I mean there should be a tie-in with that; at 7:00 a.m., it ties in with the claiming of the patients with the new—you know, if it worked out in a perfect world, and they were tied in together, they should claim in the patients

The requirement that nurses individually log into the INFUZE Board and "claim" his/her patients was not only burdensome but when not done by successors resulted in poor communication. Nurses noted that they would receive calls about patients not cared for in several days or shifts because information was not updated.

So people haven't claimed 'em, so when we start advancing technology and we do get our iPads or our cell phones or whatever it is we're going to go to, I'm going to have doctors calling me Friday night saying, "Hey, how's this kid doin'?" "I don't know. I'm not there." So you've gotta do something that electronically pushes that next nurse right into that spot.

d. Alerts and parameters

Well the doctors order it in ICS, you know? When the doctors admit a patient they write call service for vital sign, heart rate greater than 140 or less than 60. Or, you know, they put all these parameters in. So maybe they should, I mean these are all computers; they should be able to talk to each other. Why can't the INFUZE Board pull from the ICS order set and see what the doctors have specifically ordered?

one other thing I liked about it, in the beginning, um, when the IV pump stopped, if there was just occlusion or anything, if they stopped working, it would show up right away. It would start flashing, so you knew exactly what room to go into, 'cuz a lot of times, [laughter] we're walking down the hallways, trying to figure out what room it is. Like the minute you heard a pump, you could look up and see exactly what room it was in.

> *…like we said when you're really worried about alert values and you wanna know those values right away and you're, because you're going to make actions based on those values right away. Whereas you know we're on a floor so how can, how can, we don't need to know all those alerts but we can use it in other ways that will help our patient flow, you know, and help our patient care like [name 11] said about, you know, knowing the care team and knowing, you know, um, which rooms are open.*
>
> *And, you know, like our flow and our, I think that's the route we need to go instead of the alerts so much.*

2. A second theme concerned *the view* provided by the INFUZE Board. The *"quick look"* provided by the INFUZE Board was a feature appreciated by many of the nurse participants. On the other hand, quick look information that was not *tailored to the individual patient or care setting* were limitations of the quick look. Another aspect of navigating the INFUZE Board was the differentiation of *important vs unimportant information*. Nurses felt that information deemed to be unimportant to their usual work or patient needs was distracting and undermined the usefulness of the INFUZE Board.

    a. "Quick look"

Using the INFUZE Board as a quick look, big picture view of the unit was appealing to nurses. They felt that basic information needed to answer questions on the fly, for example when covering for another nurse was readily available. Those who were charge nurses reported the need for this big picture perspective and in particular used it for both patient and staff assignment making.

> *You know, I mean, when you open ICS, you open—you open the ICS, and then you have that whole, um, all the tabs on the top. And then, you have*

to click on that tab, to get to, say, vital signs. And then, you have to—when you're done with vital signs, and then you have to click and go, you know, it just seems like there's a lot of clicking. Where with the INFUZE Board, you just hover and things pop up. You know, I… do like that hover function, and things pop up easier. I just, I don't know, it just seems like everything's there on the INFUZE Board.

it's like when I'm working at a hall, and somebody asks me a question, then I can look, and it's an easy way to see, you know, the diagnosis and see the last set of vital signs, or see what they charted for their baseline and stuff. And then, I have that, you know, 'cuz it's some, you know, some questions are not straightforward. Some are, and you can just say, "Oh, well, yeah, with this surgery, you know, they can't roll on their side or whatever." But then, sometimes, you know, it's not a straightforward question and you're trying to answer somebody who needs help. So then, it kinda—I can look at that, just a quick, to see…

Like when you do resource, when, you know, if you're a resource, it's real helpful, too, though, to hover over and find out what people are, before you go in the room. Because you don't, you know, you're trying to help from potentially 44 different patients. And if you're answering lights, you can see what the, you know, their diagnosis is. And for us, some diagnoses, you know, it jumps up at you, that you gotta make sure that, you know, mobility is a certain way or, you know, I mean—

I really do like that, because I like to see that it's cleaned or, you know, and if I pass a room and don't see a patient in there, it's nice to be able to look at the INFUZE Board and see, you know, add a test or whatever. Or, you know, like I was resource the other day. I went by this room and there was no patient, and it just kinda struck me the way it was. And so, then I found the nurse who had the patient, you know, and I said, you know, "Did that person, by any chance, dismiss?" And she's like, "Oh, yeah. You know, and I got busy and I haven't let the charge nurse know." It's like, "Oh, good, we need a bed." You know, so I called up and told the secretary, "Oh, we got a bed, [laughter], we just gotta get it clean."

Another participant described how the quick view of the INFUZE Board doesn't support her clinical decision making processes.

> *And I'm—like in the back of my mind as a nurse I know my patient's here for fever neutropenia so I'm going to look at their vital signs, make sure they're not febrile, make sure they're not hypotensive and check their labs to check what their ENC is. Like I already have that thought process going on, so the INFUZE Board doesn't help me.*

b. Individualize to patient and setting.

The type and frequency of alerts were seen as both a helpful and unhelpful tool. Nurses felt that many of the alerts were not helpful because they were too generic and did not reflect the individual needs or status of an individual patient. Because of the clinical reasoning required to determine if the alert was truly an alert or just information, most felt the alerts had limited usefulness. The nurses did recognize that in more acute settings such as the ICU or ED, alerts might have more benefit than on these general care units. The opportunity to configure alerts to an individual patient or even unit population was suggested as a way to improve this feature. One focus group engaged in deeper consideration of alerts:

> *If you could put a parameter in there because you had either increased or decreased your bicarb. So if the PH is, you would put if, if, if I wanted to know when the PH is below 7 or greater than 8.5, send me an alert. If it's in the middle, I don't really need to know about it, because everything stays the same.*
>
> *But that would be so hard to standardize because only the Methotrexate patients that I'd want to know that…*

> *…If I could set up an alert…….And say, notify me for PH less than 7 or greater than 8.*
>
> *I would probably do, and if it would stay that same for the patient in your nurse to nurse report you could say I set up the INFUZE Board to alert you, like I think that'd be fantastic…*
>
> *…That would save us so many t-, so much time because we're constantly going back into ICS, seeing what the, seeing what the PH came back at. And the errors, you know, how often do you forget to check it and then you see an hour later that you should of titrated your fluid down an hour before but you didn't see it until now.*
>
> *We've got a respiratory baby that if they drop below 88 percent, you know in, in oxygen, we need to know. And if they're doing that for more than five minutes, we add oxygen to them. And so, I mean there's a lot of different parameters that would be nice if we could set as individual patients to alert us.*
>
> *Or we're just—so we have, you know many different patients with many different needs. And so if we could say, you know, or we've got a patient on a Heparin drip and we need to know what the APTT is. So the, you know, the INR. If we could put some parameters in there and say alert us if it's greater or less than these numbers, um, so I mean it's, it's kind of really patient specific some of these things.*

A third theme involved "navigating *the INFUZE Board.*" Navigation concerns included the ability to *customize the view* based on role (e.g. charge nurse, staff nurse, or resource nurse), geographic location, or patient assignment. The *screen display* was felt to be small, especially on large nursing units, limiting the ability to navigate to the correct patient. *Maneuvering the mouse* because of the small display and many icons available was a challenge. Finally, participants noted that the *placement of INFUZE Boards* needs further consideration in light of patient confidentiality and usability.

a. Customizable view

Focus group participants identified several aspects of the view presented on the INFUZE Board. Factors considered resulted in a desire for the ability to customize the view based on user role (e.g. staff vs. charge nurse) and unit. On large units especially, the desire to select a view of the patients in a particular geographic area was desired.

> *So we need to find out how to segregate those—those areas a little bit. Charge needs to have all 44 beds viewable. I need to have my wing with 10 or 12 beds viewable, you know, and each one needs to be able to be separated out.*
>
> *Or maybe just be able to call up the other hallways if you wanted to cuz I don't know how many times it's happened. Get a phone call down D hall for somebody that's down B hall. "Can I talk to the nurse who's taking care of such-and-such?"*
> *So it's kinda like, you know, in my perfect world, the PC that I'm at, it would be nice if I could just say, "I just want 3D hall today," or something like that. Yeah, because that would be more helpful when I'm doing patient care. But as charge, it's nice to be able to see everything.*

b. Screen display

The screen display was of similar discussion. In particular, participants felt the small boxes representing each patient made it difficult to maneuver on the screen, especially when a large number of patients were displayed.

> *Does the software—can it expand how big the little squares are for the room? But the square that represents their room. Or change parameters?*
>
> *Yep, I think the icons would be bigger then and I think we might look at it closer and utilize it more. It's kind of a, like you said like a video game. It's just kind of a big, blinking lights. So if we had just our, our floor that we were working with I think we would utilize it.*

> *If there was a way to do it so you don't have to, like, hover over each box to find out where you're at. You know if it would just tell you. Because it's easy to just look at a piece of paper and see these three rooms. So if we could do it that way.*

In addition to the display properties, participants noted that the icons used were not always appropriate to their practice settings.

> *Um, these are the icons that show, um, I, I don't know. I don't know where it all started with what icons to choose. If it was just like this is the way the ED started and this is the icons they used. So we're going to put this on PEDS and throw these icons the same.*

> *But even just saying, like, our INFUZE Board is not going to be the same as the ER's, is not going to be the same as Francis 1, is not going to be the same as DOM 3. Whether it's, you know, I mean our room configurations are all different but as a generalized statement, like, our units are so different. Our assignment sheets are different on every single unit. So you can't just take one tool and throw it to every unit. So even if Francis 1's observations are different than ours that doesn't necessarily mean that their observations would be helpful for their users. So, so their icons might be different. Like a Post Op floor they're big on making sure the SCD's get on within the first 24 hour period, that's a big huge thing. Just from having students on the Ortho floor I know that.*

c. Maneuvering the Mouse

In addition, to how the screen is displayed, the ability to navigate using the mouse was an important consideration. In part, the small icons and larger number of patients represented on the screen resulted in challenges maneuvering the mouse to needed information.

> *Well, I know one of the things that's really gotten me lately—because I try and use it. I really do. Um, but you move your mouse anywhere on that INFUZE Board, and a—someone's screen pops up. I'm like, "No, I don't want that one!" And to close it—*

It is too sensitive. I would much rather have to go to that room and double click on it to get my stuff to pop up. Cuz what it does now drives me nuts.

So some sort of hardware issues and being able to navigate and then the portability or feeling like you're kinda tethered—

Or even as you scroll over, if that single room just enlarges and you hit the next room, that one enlarge—you know, just so they magnify as you pass them, so you can actually select or look at the labs or whatever, but not open any windows—data windows.

d. Placement

The placement of the INFUZE Board on the unit was another consideration for nurse participants. They were concerned with maintaining patient confidentiality. There was concern that through a process of elimination, visitors would be able to determine other patients' diagnoses and problems. In addition, participants were uncertain about what to tell visitors who asked about the INFUZE Board.

one of the things we have that nice, big, huge INFUZE Board up there, and I understand patient confidentiality. However, like [name] said, if the light's going off, we have to jump through a whole bunch of hoops to find this. I honestly believe that board needs to be down in the nurses' area . Anyone, any staff can log right into there, get that whole screen up and let it be functional. Let me go over that big screen that's down by the nurses' station and see what I need to see. Don't have it up above where anyone walking by can see me hover over those lab values. Down low, a regular dedicated computer screen, whatever, so it is a quick, get in, find what you need, and move on. I think more people would use it if it was a central--at the nurses' station, that was interactive

But right now way up in the sky, it's—it's really—what's it tellin' anybody? I mean it looks good, but it's really not tellin' anybody anything because you can't do anything with it up there unless you log into the computer and sit down and, you know, you yourself or you get the iPhone or the iPad.

Right. There is no allowed interaction with it. It is strictly a screen mounted to the wall for us to view.

Do we need to explain—I mean if a parent asks us, are we to ex-, it is their child. Do we explain that or do we just say this is a tool that we use and, um, you know, I, I can't really tell you what the symbols mean.

And I also don't like that. I know it's not identifiable to the patient, but I still don't feel like—even though it's not identifiable to the patient. Families can realize oh I, my kid has this symbol. This kid has a symbol so—

the other thing that is barriers on our floor is, um, people are techy, and having those monitors in the hallway, people are—nurses are concerned that other patients are gonna figure out—

Well, we have patients who are techy.

Yeah, patients, families are techy, that other patients are gonna figure out what's going on in the hall and the other rooms, based on the icons, especially the isolation ones.

But I haven't quite seen that yet, but that was, I know, one of the fears.

You'd really have to study that board for a while [laughter]. I know what the icons are, and it's still [hard to remember]

Nurse participants engaged in lengthy discussion of the *training needed to successfully use the INFUZE Board*. Factors identified are that first, the INFUZE Board *takes effort to learn* and formal training opportunities are necessary and desired. Participants felt the *role and purpose of the INFUZE Board* was not inherently evident and needed to be part of the training in order to build buy in to the INFUZE Board's use. *Focused training close to implementation* was a key training need identified. Finally,

participants described a need for ongoing training updates and the *opportunity to provide feedback* to INFUZE Board initiatives and updates.

a. "Takes effort to learn"

Participants described their education and training to use the INFUZE Board. They noted that it does take effort to learn to use the system. Nurses noted that the absence of clear articulation of the goals and opportunities of the INFUZE Board to impact their nursing care were generally absent from the training.

b. Role and purpose

One of the challenges in learning about and using the INFUZE Board was limited understanding about its role and purpose. Participants felt that if the purpose of the INFUZE Board was more intentionally described during the education, there would be better support and use of it.

> *For a staff nurse perspective. So I just think that, um, you know it is a tool and we understand it's a tool, but what is its purpose? Are, is it a, something that you're using that someone up above is using for a data collection tool? Is it something that it's supposed to make staff's role easier? Is it supposed to help us with patient flow? I mean what is its goal and purpose? And I don't think that's really been explained to staff nurses.*
>
> *But, um, [name] and [name], our managers, were there and they were reminding us to do the INFUZE Board or something and someone had asked, like, what, why is this helpful? What does it do? And their response was well it helps us.*
>
> *And see I think we just need to know that. I mean if, if staff nurses know how it's being utilized in the background I think that that's, that could be a motivator for staff nurses to use it. But we just don't know what, what it is. We were told that*

you need to use it. You need to try it. You need to claim your patients and that's, you know, okay why? You know that's what staff nurses ask is why?

Um, and—so I have to—so I think because of that, I had to work so hard [laughter] to try to use it, because it's not second nature [laughter]. It's far from it. Um, that anything that I can glean from it then makes me happy, because it's like, "Woo hoo" [laughter].

I think it was rolled a little bit quick, too quickly. We only had, um, I know that, um, one of the nurses made a comment when we had our, our specialty day or whatever. Where they, they were explaining the different icons to us and it was like a 30 minute presentation. And then one of the nurses, one of our seasoned staff said, "Okay, so we're going to be getting education on this?" And they said, "No, this is your education."

And I agree that there hasn't been, been good follow up as far a since initiation in our, our, like you said 30 minutes of education. This is what you need to do now. And nurses are savvy, we wanna know why, what's the purpose, what, what, you know, how is this going to help me or how is this going to help data collection or research of you know the, the reasons behind it.

c. Focused training close to implementation

Nurse participants felt that the education provided served more as an introduction to the INFUZE Board than an educational program. Nurses indicated a need for focused training close to the time of implementation. The need for ongoing education was highlighted. The use of superusers as unit based resources was one solution suggested based on participant's prior experience with technology implementation.

We really weren't educated on that on how to do that. So here we can, you look at the board and it shows you when your IV is working and when it's, you know, included or what-, alarming. But yet we really weren't taught this, these are the steps you have to do to make this work and to use it.

And you know I'm in a, I'm going to take some feedback from my peer nurses who have gotten a little extra training on super user than I am just a charge nurse

saying claim your patients. You know if you show me what more I can do with this program and how it's going to help me.

Yep, when we changed from computerized charting we had super users available to help you and, and it seems like every day I learn from some, one of my other peers that says, "Hey do you know you can F12 this or do you know you can do this and it's faster." Or, you know, something like that.

Yeah, we got a little bit. But the other day, I was playing with it, and like, I miss the whole thing of when I'm charge, I'm supposed to put my name on there. And that didn't—what—we have professional days in October, and it was professional days in February that—like, "How do—how did [name] get her name up there?" And they're like, "You should know how to do that." I'm like, "I missed that part."

And like yesterday, I figured out where it said "assignments," that it listed all the nurses that had claimed and who their patients were. I don't remember that education, either. I—we got—it seems like we got—I remember getting the education of what some of the vital signs were and how to put the—the pump in and…

So, I mean, that's hard when you get—if you get—if you get education on something and you don't use it for so many weeks, I mean, I think that's harder.

If it goes house-wide, it almost seems like it would be, you know, especially if they, you know, started it kinda on a certain day, and most other units went up all together or something. It almost seems like it would be beneficial to have, like, a, you know, like a pie drop-in or something on it. Because then, people who had been on it could go and learn the new things that have changed, and how things have changed, people that have been on it. And then, people going up on it would have a chance, but there's gotta be some time when people can drop in, and it would've definitely been helpful to have some time to play with it. Because at our team's days, I don't think it was more than 20 minutes, either.

> *She talked fast and she flipped through slides. You know, and then she's like, "Okay, now, I'm actually gonna bring you guys up." "Okay," [laughter].*
>
> *My head's spinning, chu chu chu.*

Yeah, and those teams days are—Technology overload.

Those team days are filled with a lot of stuff anyway.

d. Participation in INFUZE Board development and revision.

Participants desire an opportunity to have additional discussion and feedback into the tool.

> *Yeah, I think it was also difficult. We were said, here's what we're doing. We got our 30 minutes of education on it and then we haven't really as a whole been asked for our opinion again.*
>
> *But if there was a way to say, you know to talk about the IV pump that, to mention the IV pump thing or to mention, you know, like, because we have never been followed up on our concerns. You know what do we tell the families when they ask about the board…We haven't had an opportunity to ask that question.*

Despite the identified limitations of the INFUZE Board, participants exhibited *'Optimism for what could be'.* Those participants who had *charge nurse roles* saw the INFUZE Board as a concise way to keep information at their fingertips. Using the INFUZE Board as *a means to enhance communication* was another opportunity nurses were enthusiastic about. Another opportunity was the ability to *capture device data* such as alarms from monitors.

e. 'Optimism for what could be'

    a. Use for charge

Those nurses who served in Charge Nurse roles identified the opportunity for the INFUZE Board to provide needed information at their fingertips. In addition to the things they already are able to use the INFUZE Board for (clean vs dirty rooms, patient away, isolation) …..

I use the isolation sometimes to see if they're on isolation. As a charge nurse again that is, um, I think a cha-, in a, as a charge nurse role what I would use it more as if I was able to make my assignments through there. If there was a way that I could, um, have, you know, like, like on the computer or on an iPad that I could see the INFUZE Board. And I could say, I could click on and know, you know, see their meds, see their labs, see some of that and then I could make my assignments from that. That would give me more information about the patient.

b. Communication

i. Who's the caregiver?

Nurses expressed the opportunities presented by the INFUZE Board to improve communication with both nursing and interdisciplinary teams. In particular, the ability to identify caregivers for each patient in one location for all would save time and effort in contacting an incorrect caregiver.

What the INFUZE Board could help me with would be who are the people involved in their care and who do I need to contact if this happens? Or what social worker has been seeing them…

And, um, I just thought right now, as you were saying if it went hospital wide, it would be super useful when you're floating somewhere and you don't know any of the nurses, just to be able to—'cuz people always come up and ask you, like, who's taking care of this patient. And you have no clue, so you could just pull it up on your INFUZE Board and have a picture, and this is who's taking care of it.

But if we get to where we—we carry cell phones, everyone, that will make that easier too because you look at your—you'd look at your iPad, see the list of on your—of who's got which patient and what their phone—what their number is, and then you just transfer the call right to their pocket.

That would be another thing, I've always wondered this with, like, our—I mean we have so many services and so many ancillary staff that work with our patients. And so you have a patient that's seeing physical therapy, and we have what 15

physical therapists. So you have to, like, look through the notes and see who saw them the day before. And then try to page that person, and they're like oh I'm not covering them today, call this person.
Um, so, like, if there was a set ancillary staff member assigned to those people, if you can assign those to the INFUZE Board too. So if—because physical therapy has a list of the patients, I'm seeing these patients today, you're seeing these patients today.

Nurses noted that on some units, residents have begun to use the INFUZE Board to identify the nurse caregiver. This was felt to be useful and made the nurse feel a valued member of the team.

We all started noticing that they[residents] tend to walk up to the nurse a little bit, um, more frequently and say, "You have 108," or "You have Joey in that room, and I need to know when you're gonna do vitals," or "when you're gonna get him up, so I can look at their scan," or whatever, you know? So I've started to notice that the residents are using probably a little bit more than we are, consistently.

One nurse concluded: *I think that would be the most helpful for me. Communication instead of alert.*

ii. Paging

Nurses liked the opportunity to identify the caregiver and page from the INFUZE Board. However, the paging system is populated with default return numbers which results in miscommunication if the nurse doesn't remember to change this. Aligning the INFUZE Board systems to resemble those already in use is one strategy to decrease this problem.

So I think that has potential. I like how the little service pagers, you can just click to text page them. But I think, and I talked to [name] a little about this too but it really bothers me how it automatically puts in our call back number as 55238.

Because we have to go in and delete that, because that's just our unit number, it's not your personal extension number. So I think if we just had an open text box and it didn't have any extra stuff, because that's how we're used to paging.

We're used to going to a text pager and it doesn't automatically ever input anything extra. Well and we can be in a one to one, in, in the room and text paging from there that we need an answer or we could be at several different phones.

iii. Call lights

Nurses envisioned call lights alerting via the INFUZE Board, streamlining the need for multiple systems.

> *It would be useful, I always thought if a patient puts on a call light since the INFUZE Board is right on the nurses' station.*
>
> *Why don't the call lights just show us which rooms?*
>
> *Yeah, get rid of our call light system.*
>
> *Yeah.*
>
> *And then have the box just blink.*

c. Capture device data

Participants described the desired opportunities to capture data from devices such as pulse oximeters, feeding pumps, etc.

Well, essentially, any of the equipment that we're looking at purchasing, replacing, evaluating, should have wireless capability so that way it could be added on if it's needed by that unit. You know, two feeding pumps. You know? I mean there's all sorts of things that, honestly, if they were—if they had wireless capabilities, we could tie it in and make this more useful.

Summary

The purpose of this research is to compare nurses' PU, PEU, and workload burden for the ICS and the icon-based electronic clinical dashboard system, INFUZE. Findings in general showed ICS was favored over INFUZE, except for Average NASA scores. In Chapter 5, the researcher discusses findings and implications.

Chapter 5: Discussion

Nurses' perceptions, acceptance, and utilization of EHR tools is vitally important in assuring the necessary acceptance and appropriate use of the technology (Ehteshami, 2017). While the use and evaluation of numerous types of technologies to support nursing workflow exist in the research going back three decades, none of the studies, however, applied the concepts of PU, PEU, and cognitive workload to understand the nurses' ability to retrieve relative clinical information comparing a native icon-based electronic dashboard and a core EHR.

With the legislatively mandated Health Information Technology for Economic and Clinical Health Act (HITECH Act) in 2009, the coordination of a nationwide effort to implement and use the most advanced health information technology was started (HealthData.gov, 2018). That directive, through financial incentive and disincentives, has resulted in non-federal acute care hospitals moving from a basic EHR system use rate of 9.4% in 2008 to 83.8% by 2015 (Henry et al., 2016). The race to comply has largely been successful relative to the intent of the HITECH Act, but has lacked real involvement of frontline healthcare workers, such as nurses, in providing clinical input on vendor selection, functionality, and usability. Thus, there is a desire to continually innovate beyond the tools of a core EHR and compare if natively developed electronic tools can further improve nursing workflows. New conceptual frameworks are needed to measure and understand how new electronic tools improve or don't improve the nurses' intention to use the technology.

The purpose of this research is to compare nurses' PU, PEU, and workload burden for the ICS and the icon-based electronic clinical dashboard system, INFUZE. The specific aims of this study are as follows:

Aim 1: Determine nurses' PEU of ICS as compared to INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit;

Aim 2: Determine nurses' PU of ICS as compared to INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit;

Aim 3: Determine nurses' perception of workload, using ICS as compared to INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit, and;

Aim 4: Determine nurses' perceptions of how the INFUZE Board facilitated or hindered their intention to use the tool.

The conceptual framework, TAM, was used to propose that the concepts of PU and PEU, would indicate a nurse's intention to use the INFUZE Board as compared to ICS. The closely aligned concept of workload, as measured by the NASA TLX, provided six dimensions measuring the associated factor of workload for PEU. Demographic characteristics, as well as data related to PU, PEU, and workload, were extracted and converted to a limited secondary data set from the original INFUZE nursing satisfaction evaluation. A transcript from focus group discussions related to INFUZE was also analyzed using constant comparative and content analysis. Data were analyzed using standard descriptive and inferential statistics in SPSS V21. Overall, for PEU and PU, ICS was favored over INFUZE. For workload, INFUZE was favored over ICS.

In the following sections, the study results from each aim are discussed and conclusions are drawn from the study findings. Strength and limitations of the study are described, and findings are linked to the conceptual framework of the study. Then implication for future study are discussed.

Significant Findings and Relationship to Existing Literature

Perceived Ease of Use. Aim 1 of the study was to determine nurses' PEU of ICS as compared to INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit. Overall, PEU of ICS was significantly greater than PEU of INFUZE. However, neither ICS nor INFUZE were perceived as very easy to use, with average scores more neutral than agree or disagree. Likely reasons for this may be that existing technology is perceived as easier to use than new technology, and may reflect the burden of technology change. These findings align with the focus group comments, "*It's kinda like what's the tool (INFUZE) going to do for us now, and what do we have to do for the tool, but it also seems like it's another system for us to open up" and "why would you go over here (INFUZE) when it has bits and pieces of information and ICS has everything".* This aligns with the literature on difficulty adjusting to technology change. Berg, LoCurto, & Lippoldt (2017) report the process of caring for patient by nurses is disrupted with the adoption of new technology, which may be met with resistance. In numerous studies, the nurses' perception of the information system's ease of use and usefulness had a significant impact on adoption (Hsiao, Chang, & Chen, 2011; Kowitlawakul et al., 2015; Ifinedo, 2016; Rasoulzadeh, Abbaszadeh, Zaefarian, & Khounraz, 2017; Song et al., 2015). Nurses in this study scored INFUZE low in both

PEU and PU, which would correlate with many of the thematic perceptions shared by nurses.

Perceived Usefulness. Aim 2 of the study was to determine nurses' PU of ICS as compared to INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit. Overall, PU of ICS was significantly greater than PEU of INFUZE. However, neither ICS nor INFUZE were perceived as very useful, with average scores more neutral than agree or disagree. The variable "all registered nurses" was shown to have a significant ($p<.05$) difference, favoring the use of ICS as compared to INFUZE. These findings align with the focus group comments, "*like claiming our patients, like if there was an automatic way for that to happen because I think, um, a lotta the nurses know as we come on it, it—we see it as, you know, one more thing to do to claim your patients, and you have to, you know, it's kinda cumbersome like they were saying" and "You know, and if—I think it'd be more user friendly if somehow it was* i*f there was a way that we could actually chart off the INFUZE Board, or something*." These findings align with previous research on the importance of understanding the usefulness of information displays from different clinical perspectives (Doig et al., 2011; Dowding et al., 2017; Franklin et al., 2017; Koch et al., 2012(a); S. Lee & Huebner, 2017; S. Lee, Kim, & Monsen, 2015; Schall et al., 2017).

Perception of Workload. Aim 3 of the study was to determine nurses' perception of workload, using ICS as compared to INFUZE to retrieve pertinent information relative to care of the patient and operation of the unit. The findings showed that workload burden was substantive, with scores in the medium range. Overall,

perceived workload burden of ICS was significantly greater than perceived workload burden of INFUZE. These findings align with the focus group comments, "*if don't know any of the nurses, just to be able to—'cuz people always come up and ask you, like, who's taking care of this patient. And you have no clue, so you could just pull it up on your INFUZE Board and have a picture, and this is who's taking care of it" and "one other thing I liked about it, when the IV pump stopped, if there was just occlusion or anything, it would show up right away. It would start flashing, so you knew exactly what room to go into, Like the minute you heard a pump, you could look up and see exactly what room it was in."* These findings suggest that there may be value in providing a big-picture view of nursing unit data for charge nurses, and that it may be possible to reduce workload burden with innovations in data displays, as suggested in the literature by Koch et al. (2012b) and Anders et al., (2012). Similar in one study, nurses' mean perceived mental workload scores were lower with a natively-developed integrated display and across effort, and frustration dimensions (Koch et al., 2102b).

Nurse Perceptions of INFUZE. Aim 4 of the study was to determine nurses' perceptions of how the INFUZE Board facilitated or hindered their intention to use the tool. Five major themes that emerged from the data were as follows. One, nurses felt INFUZE was "just another thing to do" amidst daily workflow routines. Two, the "view" provided by INFUZE provided quick data consumption, however the inability to individualize INFUZE based on the needs of patients or nurses was a limiting factor. Three, "navigating" INFUZE while using the mouse could be challenging due to limited display size, small icons, and large amount of data made visible. Fourth, "training" was

limited and didn't provide rationale related to the role and purpose of the INFUZE board. Last, despite the shortcomings shared by the focus group of nurses, there was "optimism for what could be" based on perceived opportunities to enhance and create functionality.

A descriptive, comparative mixed methods design was used to address the aims of this study using a secondary dataset. While the quantitative results for PEU and PU did not show any substantive comparative difference between ICS and INFUZE, the factor cognitive load did prove statistically significant that INFUZE reduced the burden compared to ICS. The study was also significant because it described the lived experiences of RNs, who used both ICS and INFUZE, and were able to describe the impact of an optimized interface using icons displayed on a digital dashboard and the core functionality of an EHR.

Theoretical Implications

The findings strongly indicated that nurses favored ICS over INFUZE for PU and PEU according to the TAM questionnaire. The NASA questionnaire, however, revealed the opposite: nurses favored INFUSE over ICS for the six dimensions of workload. Without NASA, these findings would not have been known. Thus, the NASA items were critical for understanding nurses' perceptions of ICS and INFUZE. Further research is needed to validate these findings with other technologies and interfaces.

Limitations

Limitations in the research pertained to the use of a secondary data analysis of an existing data set from a large Midwestern academic medical center. Problems with the

use of secondary data include the fact the data were not collected specifically for this research purpose, leading to potential for misinterpretation or other bias. The data was also limited to a single hospital setting, which limits the generalizability of the findings of this study in other hospitals, health systems, and regions around the country.

Lastly, limitations of focus groups can contain a tendency for one or two dominant participant to overly influence the session, thus biasing the groups output. Since the researcher used the transcripts from the original data set to complete the analysis using constant comparative and content analysis and was not present during the focus group interviews, all the non-verbal context of the participants is lost. The interaction of the focus group forms a social atmosphere and the comments should be interpreted inside of this context.

Education, Policy, and Future Research Implications

Implications for Nursing Education

Nursing informatics competencies are essential across all levels of nursing education (AACN, 2006b; AACN, 2011; AACN, 2008). Given the continuous nurse interaction with dashboards and interfaces, the ability to visualize clinical data should be included into each level of nursing curriculum to advance discovering new knowledge about patients, nursing care, and health systems and apply new insights into clinical practice to change patient outcomes (Monsen et al., 2015). Furthermore, nurses will encounter changes in technology and need to be adept at managing new technology. Simulated technologies should be included in nursing education at all levels to provide experiences with new and different technologies.

Implications for Policy and Clinical Practice

For nurses who are often busy attending to patients, it is impractical for them to be constantly monitoring an electronic health system to sieve out vital bits of patient information (Tan et al., 2013). Policy makers and hospital administrators need to assure that nursing's voice is included in decision making about technologies they use or that affect them, and that nurse time and effort is prioritized when making decisions about new technologies. This study is an exemplar of robust nurse input regarding possible technology solutions. When a large study is not possible, policy makers and hospital administrators should communicate with nurse stakeholders to ensure that the nurse's perspective is included.

Implications for Future Research

Given the limited number of studies investigating what is known about nurse clinical data consumption and management through the use of icons and digital dashboards, the potential opportunities for further research in this area are substantial. The use of a clinically integrated and comprehensive nursing dashboard can be a powerful tool because it can allow the investigator to create conditions that provide the right information, to the right nurse, at the right time. While nurses understand and appreciate the benefits of the EHR, frustration is still expressed that the EHR hinders collaboration with clinicians outside their organization and is less efficient, stealing precious direct time away from patients (HIMSS Analytics, 2015). First, it is critically important to understand the implications of the numerous disparate systems and screens used in documenting a patient's care in the complex environment of the hospital. Second, it is critical to understand how health systems can optimize the path for consuming and documenting patient information in order to improve efficiency and nurse satisfaction. Human-computer interaction studies are needed in-situ to measure and reduce the footprint of the EHR.

Finally, further research is needed to potentially incorporate new information from nurse feedback from the focus groups into the TAM. Adding more factors associated with PEU and PU, such as the culture of the work environment or risk of using new technology, could provide new information that may be important for future revisions of the TAM.

Conclusion

This descriptive, comparative mixed methods study compared nurses' PU, PEU, and workload burden for the ICS and the icon-based electronic clinical dashboard system, INFUZE. The research approach used an extended conceptual framework, utilization the TAM and NASA TLX models and the inclusion of external variables of support resources, experience, demographics, and relevance to task. The secondary dataset included ICS (N=131) questionnaire data INFUZE (n=85) questionnaire data complete between September 19, 2012 and January 31, 2013. Transcripts of three voluntary focus groups were analyzed using content analysis methods to synthesize the feedback of 13 nurse participants. For PEU and PU, ICS was favored over INFUZE. For workload, INFUZE was favored over ICS. Focus group analysis revealed that there would be value in implementing an integrated dashboard interface if it is helpful in consuming actionable data rapidly; however, if it is not helpful, the interface would be irrelevant and/or burdensome. Furthermore, nurses considered the learning curve for new technology burdensome. In summary, the use of icons and/or dashboards tailored to the specific needs of nursing has potential to improve nurses' experience, if the dashboard is a seamless part of the workflow and is integrated within existing technology. Further research is needed to understand human-computer interaction for specific interfaces in situ, toward the goal of developing an interface that is effective as an integrated and seamless companion to the core EHR.

References

American Association of College of Nursing. (2006a). AACN position statement on nursing research. http://www.aacn.nche.edu/publications/position/NsgResearch.pdf

American Association of Colleges of Nursing (2008). The Essentials of Baccalaureate Education for Professional Nursing Practice. Available at http://www.aacnnursing.org/Portals/42/Publications/BaccEssentials08.pdf. Accessed July 14, 2018.

American Association of Colleges of Nursing (2011). The Essentials of Master's Education in Nursing. Available at http://www.aacnnursing.org/Portals/42/Publications/MastersEssentials11.pdf?ver=2017-06-28-140512-827. Accessed July 14, 2018.

American Association of Colleges of Nursing (2006b). The Essentials of Doctoral Education for Advanced Nursing Practice. Available at: http://www.aacnnursing.org/Portals/42/Publications/DNPEssentials.pdf Accessed July 14, 2018.

American Nurses Association. (2015). *Nursing informatics: Scope and standards of practice* (2nd ed.). Silver Spring, Maryland: Nursesbooks.org.

Batley, N. J., Osman, H. O., Kazzi, A. A., & Musallam, K. M. (2011). Implementation of an emergency department computer system: Design features that users value. *Journal of Emergency Medicine, 41*(6), 693-700. doi: http://dx.doi.org/10.1016/j.jemermed.2010.05.014

Berg, G. M., LoCurto, J., & Lippoldt, D. (2017). Stages of adoption concern and technology acceptance in a critical care nursing unit. *The Journal of Nursing Administration, 47(9)*, 441-447.

Blignaunt, P. J., & McDonald, T. (1999). The user interface for a computerized patient record system for primary health care in a third world environment. *Journal of End User Computing, 11*(2), 29-34.

Bodenheimer, T., & Sinsky, C. (2014). From Triple to Quadruple Aim: Care of the Patient Requires Care of the Provider. *Annals of Family Medicine*, *12*(6), 573–576. http://doi.org/10.1370/afm.1713

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Qutart*., 13, 319-339.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35*(8), 982-1003.

Doig, A. K., Drews, F. A., & Keefe, M. R. (2011). Informing the design of hemodynamic monitoring displays. *CIN: Computers, Informatics, Nursing, 29(12).* 706-713.

Dowding, D., Merrill, J., Onorato, N., Barron, Y., Rosati, R., & Russell, D. (2017). The impact of home care nurses' numeracy and graph literacy on comprehension of visual display information; implications for dashboard design. *Journal of the American Medical Informatics Association, 0*(0), 1. doi:10.1093/jamia/ocx042

Dowding, D., Randell, R., Gardner, P., Fitzpatrick, G., Dykes, P., Favela, J., . . . Currie, L. (2015). *Dashboards for improving patient care: Review of the literature* doi: 10.1016/j.ijmedinf.2014.10.001

Duffy, M. (2015). Nurses and the migration to electronic health records. *The American Journal of Nursing, 115*(12), 61-66. doi:10.1097/01.NAJ.0000475294.12738.83 [doi]

Dunn, S. L., Arslanian-Engoren, C., DeKoekkoek, T., Jadack, R., & Scott, L. D. (2015). Secondary data analysis as an efficient and effective approach to nursing research. *Western Journal of Nursing Research 37(10),* 1295-1307.

Ehteshami, A. (2017). Barcode Technology Acceptance and Utilization in Health Information Management Department at Academic Hospitals According to Technology Acceptance Model. *Acta Informatica Medica*, *25*(1), 4–8. http://doi.org/10.5455/aim.2017.25.4-8

Franklin, A., Gantela, S., Shifarraw, S., Johnson, T. R., Robinson, D. J., King, B. R., . . . Okafor, N. G. (2017). *Dashboard visualizations: Supporting real-time throughput decision-making* doi: 10.1016/j.jbi.2017.05.024

Gurses, A. P., Xiao, Y., & Hu, P. (2009). User-designed information tools to support communication and care coordination in a trauma hospital. *Journal of Biomedical Informatics, 42*(4), 667-677.

Hadorn, F., Comte, P., Foucault, E., Morin, D., & Hugli, O. (2016). Task-shifting using a pain management protocol in an emergency care service: Nurses' perception through

the eye of the rogers's diffusion of innovation theory. *Pain Management Nursing, 17*(1), 80-87.

Hart, S. G. (2006). NASA-task load index (NASA-TLX); 20 years later. Paper presented at the *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 50*(9), 904-908.

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (task load index): Results of empirical and theoretical research. *Advances in Psychology, 52*, 139-183.

HealthData.gov. Office of the National Coordinator for Health Information Technology, 2018, https://www.healthdata.gov/group/office-national-coordinator-health-information-technology. Accessed 10 Apr. 2018.

Henry, J., Pylypchuk, Y., Searcy T. & Patel V. (May 2016). Adoption of Electronic Health Record Systems among U.S. Non-Federal Acute Care Hospitals: 2008-2015. ONC Data Brief, no.35. Office of the National Coordinator for Health Information Technology: Washington DC.

HIMSS Analytics. (2015). EHR impact on nurse workflow: Increased patient safety, reduced efficiency. Retrieved from http://landing.allscripts.com/rs/allscriptshealthcare/images/Whitepaper_Allscripts_White%20Paper_NursesSurvey_FINAL.pdf

Hoonakker, P., Carayon, P., Gurses, A., Brown, R., McGuire, K., Khunlertkit, A., & Walker, J. M. (2011). Measuring Workload of ICU Nurses with a Questionnaire Survery: The NASA Task Load Index (TLX). *IIE Transactions on Healthcare Systems Engineering*, *1*(2), 131–143. doi: 10.1080/19488300.2011.609524

Hsiao, J., Chang, H., & Chen, R. (2011). A study of factors affecting acceptance of hospital information systems: A nursing perspective. *Journal of Nursing Research, 19*(2), 150-159.

Hurley, A. C., Dykes, P. C., Carroll, D. L., Dykes, J. S., & Middleton, B. (2009). Fall TIP: validation of icons to communicate fall risk status and tailored interventions to prevent patient falls. *Studies in health technology and informatics*, *146*, 455–459.

Hyun, S., Johnson, S. B., Stetson, P. D., & Bakken, S. (2009). Development and evaluation of nursing user interface screens using multiple methods. *Journal of Biomedical Informatics, 42*(6), 1004-1012.

Institute for Healthcare Improvement. (2016). Triple aim - the best care for the whole population at the lowest cost. Retrieved from http://www.ihi.org/engage/initiatives/tripleaim/pages/default.aspx

Koch, S. H., Weir, C., Haar, M., Staggers, N., Agutter, J., Görges, M., & Westenskow, D. (2012a). Intensive care unit nurses' information needs and recommendations for integrated displays to improve nurses' situation awareness. *Journal of the American Medical Informatics Association, 19*(4), 583-590 8p. doi:10.1136/amiajnl-2011-000678

Koch, S. H., Westenskow, D., Weir, C., Agutter, J., Haar, M., Gorges, M., . . . Staggers, N. (2012b). ICU nurses' evaluations of integrated information displays on user satisfaction and perceived mental workload. *Studies in Health Technology & Informatics, 180*, 383-387. Retrieved from http://login.ezproxy.lib.umn.edu/login?url=http://ovidsp.ovid.com/ovidweb.cgi?T=J

S&CSC=Y&NEWS=N&PAGE=fulltext&D=medl&AN=22874217; http://primo.lib.umn.edu/openurl/TWINCITIES/TWINCITIES_SP?sid=OVID:medline&id=pmid:22874217&id=doi:&issn=0926-9630&isbn=&volume=180&issue=&spage=383&pages=383-7&date=2012&title=Studies+in+Health+Technology+%26+Informatics&atitle=ICU+nurses%27+evaluations+of+integrated+information+displays+on+user+satisfaction+and+perceived+mental+workload.&aulast=Koch&pid=%3Cauthor%3EKoch+SH%3BWestenskow+D%3BWeir+C%3BAgutter+J%3BHaar+M%3BGorges+M%3BLiu+D%3BStaggers+N%3C%2Fauthor%3E&%3CAN%3E22874217%3C%2FAN%3E&%3CDT%3EJournal+Article%3C%2FDT%3E

Kowitlawakul, Y., Chan, S. W. C., Pulcini, J., & Wang, W. (2015). Factors influencing nursing students' acceptance of electronic health records for nursing education (EHRNE) software program. *Nurse Education Today, 35*(1), 189-194. doi:10.1016/j.nedt.2014.05.010

Krippendorff, K. (2004). *Content analysis: An introduction to its methodology* Sage.

Krueger, R. A., & Casey, M. A. (2014). *Focus groups: A practical guide for applied research* Sage publications.

Larsson H., Tegern M., Monnier A., Skoglund J., Helander C., Persson E., Malm, C., Broman, L., & Aasa, U. (2015). Content Validity Index and Intra- and Inter-Rater Reliability of a New Muscle Strength/Endurance Test Battery for Swedish Soldiers. *PLoS ONE*, 10(7): e0132185. doi: 10.1371/journal.pone.0132185

Lee, S. & Huebner, T. (2017). A home care practice scenario using clinical dashboards. *Home Healthcare Now, 35(2)*, 83-95.

Lee, K., Jung, S. Y., Hwang, H., Yoo, S., Baek, H. Y., Baek, R., & Kim, S. (2017). A novel concept for integrating and delivering health information using a comprehensive digital dashboard: An analysis of healthcare professionals' intention to adopt a new system and the trend of its real usage. *International Journal of Medical Informatics, 97*(Supplement C), 98-108. doi:https://doi.org/10.1016/j.ijmedinf.2016.10.001

Lee, S., Kim, E., & Monsen, K. A. (2015). Public health nurse perceptions of Omaha system data visualization. *International Journal of Medical Informatics, 84*(10), 826-834 9p. doi:10.1016/j.ijmedinf.2015.06.010

Manojlovich, M., Harrod, M., Holtz, B., Hofer, T., Kuhn, L., & Krein, S. L. (2015). The use of multiple qualitative methods to characterize communication events between physicians and nurses. *Health Communication, 30*(1), 61-69. doi:10.1080/10410236.2013.835894

McGonigle, D., Hunter, K., Sipes, C., & Hebda, T. (2014). Why nurses need to understand nursing informatics. *Aorn J, 100*(3), 324-327. doi:10.1016/j.aorn.2014.06.012

Monsen, K. A., Peterson, J. J., Mathiason, M. A., Kim, E., Lee, S., Chi, C. L., & Pieczkiewicz, D. S. (2015). Data visualization techniques to showcase nursing care quality. Computers, informatics, nursing, 33(10), 417-426. doi:10.1097/CIN.0000000000000190

Norris, B. (2012). The diversity of human factors: Illustrating the relevance for nursing. *Nursing Standard, 26*(33), 35-40. Retrieved from http://login.ezproxy.lib.umn.edu/login?url=http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medl&AN=22616267; http://primo.lib.umn.edu/openurl/TWINCITIES/TWINCITIES_SP?sid=OVID:medline&id=pmid:22616267&id=doi:&issn=0029-6570&isbn=&volume=26&issue=33&spage=35&pages=35-40&date=2012&title=Nursing+Standard&atitle=The+diversity+of+human+factors%3A+illustrating+the+relevance+for+nursing.&aulast=Norris&pid=%3Cauthor%3ENorris+B%3C%2Fauthor%3E&%3CAN%3E22616267%3C%2FAN%3E&%3CDT%3EJournal+Article%3C%2FDT%3E

O'Connor, C., Friedrich, J. O., Scales, D. C., & Adhikari, N. K. J. (2009). The use of wireless E-mail to improve healthcare team communication. *Journal of the American Medical Informatics Association, 16*(5), 705-713. doi:10.1197/jamia.M2299

Popovici, I., Morita, P. P., Doran, D., Lapinsky, S., Morra, D., Shier, A., . . . Cafazzo, J. A. (2015). Technological aspects of hospital communication challenges: An observational study. *International Journal for Quality in Health Care: Journal of the International Society for Quality in Health Care / ISQua, 27*(3), 183-188. doi:10.1093/intqhc/mzv016 [doi]

Rasoulzadeh, N., Abbaszadeh, A., Zaefarian, R., & Khounraz, F. (2017). Nurses view on accepting the creation of a nurses' health monitoring system. *Electronic Physician, 9*(5), 4454-4460.

Robinson, L. (2009). A summary of diffusion of innovations. *Enabling Change,*

Rogers, E. M. (Ed.). (2003). *Diffusion of innovation* (5th ed.). New York: Free Press.

Rogers, E. M. (2004). A prospective and retrospective look at the diffusion model. *Journal of Health Communication, 9*, 13-19. doi:10.1080/10810730490271449

Ruiter, H., Liaschenko, J., & Angus, J. (2016). Problems with the electronic health record. *Nursing Philosophy, 17*(1), 49-58.

Salman, Y. B., Cheng, H., & Patterson, P. E. (2012). Icon and user interface design for emergency medical information systems: a case study. *International Journal of Medical Informatics, 81*(1), 29-35.

Sassen, E. J. (2009). Love, hate, or indifference: how nurses really feel about the electronic health record system. *CIN: Computers, Informatics, Nursing, 27*(5), 281-287.

Schall, M. C., Cullen, L., Pennathur, P., Chen, H., Burrell, K., & Matthews, G. (2017). Usability evaluation and implementation of a health information technology dashboard of evidence-based quality indicatiors. *CIN: Computers, Informatics, Nursing, 35*(6), 281. doi:10.1097/CIN.0000000000000325

Sidebottom, A. C., Collins, B., Winden, T. J., Knutson, A., & Britt, H. R. (2012). Reactions of nurses to the use of electronic health record alert features in an inpatient setting. *CIN: Computers, Informatics, Nursing, 30*(4), 218-226. Retrieved from

http://login.ezproxy.lib.umn.edu/login?url=http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medl&AN=22045117; http://primo.lib.umn.edu/openurl/TWINCITIES/TWINCITIES_SP?sid=OVID:medline&id=pmid:22045117&id=doi:10.1097%2FNCN.0b013e3182343e8f&issn=1538-2931&isbn=&volume=30&issue=4&spage=218&pages=218-26%3B+quiz+227-8&date=2012&title=CIN%3A+Computers%2C+Informatics%2C+Nursing&atitle=Reactions+of+nurses+to+the+use+of+electronic+health+record+alert+features+in+an+inpatient+setting.&aulast=Sidebottom&pid=%3Cauthor%3ESidebottom+AC%3BCollins+B%3BWinden+TJ%3BKnutson+A%3BBritt+HR%3C%2Fauthor%3E&%3CAN%3E22045117%3C%2FAN%3E&%3CDT%3EJournal+Article%3C%2FDT%3E

Song, L., Park, B., & Oh, K. M. (2015). Analysis of the technology acceptance model in examining hospital nurses' behavioral intentions toward the use of bar code medication administration. *Computers, Informatics, Nursing : CIN, 33*(4), 157-165. doi:10.1097/CIN.0000000000000143 [doi]

Tan, Y., Hii, J., Chan, K., Sardual, R., & Mah, B. (2013). An electronic dashboard to improve nursing care. *Studies in Health Technology & Informatics, 192*, 190-194. Retrieved from http://login.ezproxy.lib.umn.edu/login?url=http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medl&AN=23920542; http://primo.lib.umn.edu/openurl/TWINCITIES/TWINCITIES_SP?sid=OVID:medline&id=pmid:23920542&id=doi:&issn=0926-

9630&isbn=&volume=192&issue=&spage=190&pages=190-4&date=2013&title=Studies+in+Health+Technology+%26+Informatics&atitle=An+electronic+dashboard+to+improve+nursing+care.&aulast=Tan&pid=%3Cauthor%3ETan+YM%3BHii+J%3BChan+K%3BSardual+R%3BMah+B%3C%2Fauthor%3E&%3CAN%3E23920542%3C%2FAN%3E&%3CDT%3EJournal+Article%3C%2FDT%3E

Tasa, U. B., Ozcan, O., Yantac, A. E., & Unluer, A. (2008). A case study on better iconographic design in electronic medical records' user interface. *Informatics for Health and Social Care, 33*(2), 125-138.

Tielbur, B. R., Rice Cella, D. E., Currie, A., Roach, J. D., Mattingly, B., Boone, J., . . . Charles, P. D. (2015). Discharge huddle outfitted with mobile technology improves efficiency of transitioning stroke patients into follow-up care. *American Journal of Medical Quality: The Official Journal of the American College of Medical Quality, 30*(1), 36-44. doi:10.1177/1062860613510964 [doi]

Venkatesh, V. (2000). Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model. *Information Systems Research, 11*(4), 342-365.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*(2), 186-204.

Wilbanks, B. A., & Langford, P. A. (2014). A review of dashboards for data analytics in nursing. *CIN: Computers, Informatics, Nursing, 32(11),* 545-549.

Zaydfudim, V., Dossett, L. A., Starmer, J. M., Arbogast, P. G., Feurer, I. D., Ray, W. A., . . . Pinson, C. W. (2009). Implementation of a real-time compliance dashboard to help reduce SICU ventilator-associated pneumonia with the ventilator bundle. *Archives of Surgery, 144*(7), 656-662. doi: http://dx.doi.org/10.1001/archsurg.2009.117

Zhang, H., Cocosila, M., & Archer, N. (2010). Factors of adoption of mobile information technology by homecare nurses. *CIN: Computers, Informatics, Nursing, 28*(1), 49-56.

Appendix A

ICS Questionnaire

Demographics

Last Five Digits of Phone Number (enter number)
Unit (drop down): • Do3D • Fr1C • Fr3C
Age (enter number)
Gender (drop down): • Female • Male
Education (drop down): • Associate • Bachelor's • Master's • Doctoral
Number of Years of Nursing Experience (enter number)
Are you a charge nurse? (drop down): (this will determine if charge nurse questions are presented or not) • Yes • No
Do you own a computer? (drop down): • Yes If yes, how many hours do you use personal computer each week? • No
Rate your comfort level using technology (drop down): • Very comfortable • Comfortable • Neutral • Uncomfortable • Very uncomfortable
Do you own and use a cell/smart phone? (drop down) • Yes If yes, select all functionality that applies • Voicemail • Texting • Web browsing • E-mail

- Photos
- Social networking
- Music

- No

Perceived Ease of Use

Question	Strongly Agree 1	2	Neutral 3	4	Strongly Disagree 5
1. I find the ICS easy to use					
2. I find the ICS easy to use for patient demographics					
3. I find the ICS easy to use for chief complaint					
4. I find the ICS easy to use for admission medical diagnosis					
5. I find the ICS easy to use for significant medical/surgical history					
6. I find the ICS easy to use for isolation status					
7. I find the ICS easy to use for primary service identification					
8. I find the ICS easy to use for radiology reports					
9. I find the ICS easy to use for vital signs					
10. I find the ICS easy to use for new orders					
11. I find the ICS easy to use for laboratory results					
12. I find the ICS easy to use for care provider					
13. I find the ICS easy to use for BID assessment					
14. I find the ICS easy to use for IV fluid status					
15. I find the ICS easy to recognize who the primary nurse caring for the patient is					
16. Learning to operate the ICS was easy for me					
17. Interaction with the ICS is often difficult					
18. I find it easy to get the ICS to do what I want it to do					
19. The ICS is rigid and inflexible to interact with					
20. Interacting with the ICS requires a lot of mental effort					
21. My interaction with the ICS is clear and understandable					
22. I feel that it takes a lot of effort to become skillful at using the ICS					
23. Overall, I feel that the ICS is easy to use					

Perceived Usefulness

Question	Strongly Agree 1	2	Neutral 3	4	Strongly Disagree 5
24.	Using the ICS improves the quality of work I do				
25.	Using the ICS for patient demographics improves the quality of work I do				
26.	Using the ICS for chief complaint improves the quality of work I do				
27.	Using the ICS for admission medical diagnosis improves the quality of work I do				
28.	Using the ICS for significant medical/surgical history improves the quality of work I do				
29.	Using the ICS for isolation status improves the quality of work I do				
30.	Using the ICS for primary service improves the quality of work I do				
31.	Using the ICS for radiology reports improves the quality of work I do				
32.	Using the ICS for vital signs improves the quality of work I do				
33.	Using the ICS for new orders improves the quality of work I do				
34.	Using the ICS for laboratory results improves the quality of work I do				
35.	Using the ICS for care provider improves the quality of work I do				
36.	Using the ICS for BID assessment improves the quality of work I do				
37.	Using the ICS for IV fluid status improves the quality of work I do				
38.	Using the ICS gives me greater control over my work				
39.	The ICS enables me to accomplish tasks more quickly				
40.	The ICS supports critical aspects of my job				
41.	Using the ICS increases my productivity				
42.	Using the ICS improves my job performance				
43.	Using the ICS allows me to accomplish more work than would otherwise be possible				
44.	Using the ICS enhances my effectiveness on the job				
45.	Using the ICS makes it easier to do my job				
46.	Overall, I feel the ICS is useful in my job				

Charge Nurses: Perceived Ease of Use

Question	Strongly Agree 1	2	Neutral 3	4	Strongly Disagree 5
47.	I find the ICS easy to use				
48.	I find the ICS easy to use for patient placement				
49.	I find the ICS easy to use for room descriptions (Large, small, ante room, PEMU)				
50.	I find the ICS easy to use for unit census				
51.	I find the ICS easy to use for admissions				

52.	I find the ICS easy to use for discharges
53.	I find the ICS easy to use for room cleaning
54.	Learning to operate the ICS was easy for me
55.	Interaction with the ICS is often difficult
56.	I find it easy to get the ICS to do what I want it to do
57.	The ICS is rigid and inflexible to interact with
58.	Interacting with the ICS requires a lot of mental effort
59.	My interaction with the ICS is clear and understandable
60.	I feel that it takes a lot of effort to become skillful at using the ICS
61.	Overall, I feel that the ICS is easy to use

Charge Nurses: Perceived Usefulness

Question	Strongly Agree 1	2	Neutral 3	4	Strongly Disagree 5
62.	Using the ICS improves the quality of work I do				
63.	Using the ICS for patient placement improves the quality of work I do				
64.	Using the ICS for room descriptions (Large, small, ante room, PEMU) improves the quality of work I do				
65.	Using the ICS for unit census improves the quality of work I do				
66.	Using the ICS for admissions improves the quality of work I do				
67.	Using the ICS for discharges improves the quality of work I do				
68.	Using the ICS for room cleaning improves the quality of work I do				
69.	Using the ICS gives me greater control over my work				
70.	The ICS enables me to accomplish tasks more quickly				
71.	The ICS supports critical aspects of my job				
72.	Using the ICS increases my productivity				
73.	Using the ICS improves my job performance				
74.	Using the ICS allows me to accomplish more work than would otherwise be possible				
75.	Using the ICS enhances my effectiveness on the job				
76.	Using the ICS makes it easier to do my job				
77.	Overall, I feel the ICS is useful in my job				

(Dillon, McDowell, Salimian, & Conklin, 1989; Hyun, Johnson, Stetson, & Bakken, 2009).

NASA Index Tool Questionnaire

Hart and Staveland's NASA Task Load Index (TLX) method assesses five workload demands on a 7-point scale. Increments of high, medium, and low estimates for each point result in 21 gradations on the scale.

Mental Demand

How mentally demanding was the ICS?

Physical Demand

How physically demanding was the ICS?

Temporal Demand

How hurried or rush was the pace of using the ICS?

Performance

How successful were you in accomplishing what you were asked to do with the ICS?

Effort

How hard did you have to work to accomplish your level of performance?

Frustration

How insecure, discouraged, irritated, stressed, and annoyed were you using the ICS?

(NASA TLX: Task Load Index, n.d.).

Appendix B

INFUZE Questionnaire

Demographics

Last Five Digits of Phone Number (enter number)
Unit (drop down): • Do3D • Fr1C • Fr3C
Age (enter number)
Gender (drop down): • Female • Male
Education (drop down): • Associate • Bachelor's • Master's • Doctoral
Number of Years of Nursing Experience (enter number)
Are you a charge nurse? (drop down): (this will determine if charge nurse questions are presented or not) • Yes • No
Do you own a computer? (drop down): • Yes If yes, how many hours do you use your personal computer each week? • No
Rate your comfort level using technology (drop down): • Very comfortable • Comfortable • Neutral • Uncomfortable • Very uncomfortable
Do you own and use a cell/smart phone? (drop down) • Yes If yes, select all functionality that applies • Voicemail • Texting • Web browsing • E-mail

- Photos
- Social networking
- Music

- No

Perceived Ease of Use

Question	Strongly Agree 1	2	Neutral 3	4	Strongly Disagree 5
78. I find INFUZE easy to use					
79. I find INFUZE easy to use for patient demographics					
80. I find INFUZE easy to use for chief complaint					
81. I find INFUZE easy to use for admission medical diagnosis					
82. I find INFUZE easy to use for significant medical/surgical history					
83. I find INFUZE easy to use for isolation status					
84. I find INFUZE easy to use for primary service					
85. I find INFUZE easy to use for radiology reports					
86. I find INFUZE easy to use for vital signs					
87. I find INFUZE easy to use for new orders					
88. I find INFUZE easy to use for laboratory results					
89. I find INFUZE easy to use for care provider					
90. I find INFUZE easy to use for BID assessment					
91. I find INFUZE easy to use for IV fluid status					
92. I find INFUZE easy to recognize who the primary nurse caring for the patient is					
93. Learning to operate INFUZE was easy for me					
94. Interaction with INFUZE is often difficult					
95. I find it easy to get INFUZE to do what I want it to do					
96. INFUZE is rigid and inflexible to interact with					
97. Interacting with INFUZE requires a lot of mental effort					
98. My interaction with INFUZE is clear and understandable					
99. I feel that it takes a lot of effort to become skillful at using INFUZE					
100. Overall, I feel that INFUZE is easy to use					

Perceived Usefulness

Question	Strongly Agree 1	2	Neutral 3	4	Strongly Disagree 5
101. Using INFUZE improves the quality of work I do					
102. Using INFUZE for patient demographics improves the quality of work I do					
103. Using INFUZE for chief complaint improves the quality of work I do					
104. Using INFUZE for admission medical diagnosis improves the quality of work I do					
105. Using INFUZE for significant medical/surgical history improves the quality of work I do					
106. Using INFUZE for isolation status improves the quality of work I do					
107. Using INFUZE for primary service improves the quality of work I do					
108. Using INFUZE for radiology reports improves the quality of work I do					
109. Using INFUZE for vital signs improves the quality of work I do					
110. Using INFUZE for new orders improves the quality of work I do					
111. Using INFUZE for laboratory results improves the quality of work I do					
112. Using INFUZE for care provider improves the quality of work I do					
113. Using INFUZE for BID assessment improves the quality of work I do					
114. Using INFUZE for IV fluid status improves the quality of work I do					
115. Using INFUZE gives me greater control over my work					
116. INFUZE enables me to accomplish tasks more quickly					
117. INFUZE supports critical aspects of my job					
118. Using INFUZE increases my productivity					
119. Using INFUZE improves my job performance					
120. Using INFUZE allows me to accomplish more work than would otherwise be possible					
121. Using INFUZE enhances my effectiveness on the job					
122. Using INFUZE makes it easier to do my job					
123. Overall, I feel INFUZE is useful in my job					

Charge Nurse: Perceived Ease of Use

Question	Strongly Agree 1	2	Neutral 3	4	Strongly Disagree 5
124. I find INFUZE easy to use					
125. I find INFUZE easy to use for patient placement					
126. I find INFUZE easy to use for room descriptions (Large, small, ante room, PEMU)					
127. I find INFUZE easy to use for unit census					
128. I find INFUZE easy to use for admissions					
129. I find INFUZE easy to use for discharges					
130. I find INFUZE easy to use for room cleaning					
131. Learning to operate INFUZE was easy for me					
132. Interaction with INFUZE is often difficult					
133. I find it easy to get INFUZE to do what I want it to do					
134. INFUZE is rigid and inflexible to interact with					
135. Interacting with INFUZE requires a lot of mental effort					
136. My interaction with INFUZE is clear and understandable					
137. I feel that it takes a lot of effort to become skillful at using INFUZE					
138. Overall, I feel that INFUZE is easy to use					

Charge Nurse: Perceived Usefulness

Question	Strongly Agree 1	2	Neutral 3	4	Strongly Disagree 5
139. Using INFUZE improves the quality of work I do					
140. Using INFUZE for patient placement improves the quality of work I do					
141. Using INFUZE for room descriptions (Large, small, ante room, PEMU) improves the quality of work I do					
142. Using INFUZE for unit census improves the quality of work I do					
143. Using INFUZE for admissions improves the quality of work I do					
144. Using INFUZE for discharges improves the quality of work I do					
145. Using INFUZE for room cleaning improves the quality of work I do					
146. Using INFUZE gives me greater control over my work					
147. INFUZE enables me to accomplish tasks more quickly					
148. INFUZE supports critical aspects of my job					
149. Using INFUZE increases my productivity					
150. Using INFUZE improves my job performance					
151. Using INFUZE allows me to accomplish more work than would otherwise be possible					
152. Using INFUZE enhances my effectiveness on the job					
153. Using INFUZE makes it easier to do my job					

154. Overall, I feel INFUZE is useful in my job

(Dillon, McDowell, Salimian, & Conklin, 1989; Hyun, Johnson, Stetson, & Bakken, 2009).

NASA Index Tool Questionnaire

Please rate the challenges of working with INFUZE on the scales below. 1 indicates very easy and 7 indicates very difficult.

Mental Demand

How mentally demanding was INFUZE?

Physical Demand

How physically demanding was INFUZE?

Temporal Demand

How hurried or rush was the pace of using INFUZE?

Performance

How successful were you in accomplishing what you were asked to do with INFUZE?

Effort

How hard did you have to work to accomplish your level of performance?

Frustration

How insecure, discouraged, irritated, stressed, and annoyed were you using INFUZE?

(NASA TLX: Task Load Index, n.d.).

Appendix C

INFUZE Focus Group Interview Guide

Opening Question:

1. Let's begin. Let's find out more about each other but going around the table one at a time. Tell us your name and what grade, A-F, you would give INFUZE as a useful tool for nurses.

We aren't going to go around the table anymore, so just jump into the conversation whenever you want.

Introductory Question:

2. As I said earlier, we are interested in your experience using ICS and INFUZE icon interface system in your clinical practice. The grades you indicated a minute ago ranged from ____ to ____. Please describe the things that helped you determine the grade you gave.

Transition Questions:

3. Think back to when you first began using INFUZE. What were your first impressions?
4. What was the start up process like for you? (probes could include need for education/training, incorporation into daily work, need for information)

Key Questions:

5. What was particularly helpful in INFUZE implementation?
6. In what ways has INFUZE been particularly helpful to you?

Additional Probes:

a. In what ways does INFUZE affect your efficiency in accessing information required for providing care to your patients—this could be either positively or negatively?

7. What has been particularly frustrating about using INFUZE?

Additional Probes:

a. When using INFUZE, what information is most/least valuable? What information do you look at first?
b. Describe your perspectives on the size and location of the INFUZE display.

Ending Questions:

8. If you had a chance to give advice or feedback to the developers of INFUZE, what advice would you give?

9. We want you to help us in evaluating this tool. We want to know how to improve it and what difference it made to your practice. Is there anything that we missed? Is there anything that you came wanting to say that you didn't get a chance to say?

Probes used to elicit more depth or meaning:

Would explain more about that?

Can you give us an example?

Would you say more?

Tell us more.

Say more.

Is there anything else?

Please describe what you mean.

I don't understand.