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Optimization of Simulated Electronic Medication Administration for Safe Management During Nursing Education

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ABSTRACT

Background: Academic institutions have begun to implement electronic medication administration record (eMAR) technologies into simulated education for undergraduate nursing students. As these technologies are adopted, there is an increasing need to develop insights toward optimal medication administration practices, including the decision-making processes undertaken by nursing students.

Research Question: How do nursing students generate optimized medication administration processes using eMAR technology in simulated clinical practice?

Method: This study is underpinned by the theoretical lens of interdependent, cooperative Game Theory. Primary data collection was conducted using direct participant observation of nursing students administering medications using a simulated eMAR system and a semi-structured interview following the observation. The participants reacted to different scenarios that challenged the College of Nurses of Ontario's medication administration heuristic of *Clear*, *Complete*, and *Appropriate*. Findings were individually and collectively summarized, including detailed descriptions of the participants' actions and decision-making processes, visualized on Game Theory-informed payoff matrices.

Findings: A number of different findings were uncovered in this study. The repeated occurrence of a *no relationship* interaction between the student and eMAR; the inappropriate use of the *Medication Rights* heuristic during the administration process; and, the inherent trust in the eMAR system to be correct or assist in situations of uncertainty.

Conclusion: New insights into the complex relationships created between nursing students and an eMAR system have been explored. The dynamic relationship between eMAR administration best practice principles and process efficiency warrants further examination.

Keywords: Electronic medication administration; eMAR; game theory; nursing students; nursing education; patient safety; best practice; optimization

SUMMARY FOR LAY AUDIENCE

Schools of nursing have begun to implement electronic medication administration record (eMAR) technologies into simulated education. As these technologies are adopted, education and optimization practices need to be explored based on how students interact with this technology. Participants displayed their understanding of eMAR use through demonstrations that challenged nursing's regulatory college's *Best Practice* for medication administration. These demonstrations were examined under the application of Game Theory principles which helped to define patterns of participant decision-making. A number of different findings were uncovered in this study including the occurrence of a *no relationship* interaction between the student and eMAR; the inappropriate use of the *Medication Rights* heuristic during the administration process; and, the inherent trust in the eMAR system to be correct or assist in situations of uncertainty. Based on these findings, this area of research warrants further investigation.

CO-AUTHORSHIP STATEMENT

Laura Brennan was able to complete this thesis work under the supervision and guidance of Dr. Richard Booth and Dr. Kim Jackson. Should publications result from this manuscript, their names will appear as co-authors.

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CHAPTER ONE

Background and Significance

Electronic Medication Administration

Electronic medication administration is the use of technology to complete the ordering, confirmation, and dispensing of medication via an electronic platform (Staggers, Kobus, & Brown, 2007). The type of healthcare technology used to perform this medication administration is commonly known as an *electronic medication administration record* (eMAR) system. An eMAR system generally consists of a physical computer mounted on a mobile workstation that is connected to a barcode scanner. The eMAR software is displayed on the computer screen and uses barcode scanning technology to positively identify both patients and medications and document the administration of medications (i.e., closed-loop medication administration) (Booth, Sinclair, Brennan, & Strudwick, 2017a; Booth et al., 2017b; San, Lin, & Fai, 2012). To date, eMAR systems have been implemented in numerous healthcare environments, including hospitals, clinics, and long-term care settings (Marasinghe, 2015; Staggers, Iribarren, Guo, & Weir, 2015; Warren & Connors, 2007). The development of these systems was stimulated by the need to improve the management of medication administration by nurses in acute care facilities and to manage the risks associated with the administration of these medications. Annually, billions of dollars are spent by facilities in both the United States and Canada mitigating and responding to adverse medication events (Gellert et al., 2017; Hawkins, Nickman, & Morse, 2017; Mcbee, 2019). eMAR systems have been shown to effectively reduce errors and decrease the rates of adverse medication events (Franklin, O'Grady, Donyai, Jacklin, & Barber, 2007; Gellert et al., 2017). With the transition to eMAR systems in many clinical practice environments, a sizable amount of research has been conducted exploring the advantages associated with eMAR in terms of improvements to patient safety. While the field of research exploring eMAR technology is diverse, there is a general consensus that these forms of administration technologies reduce the rates of medication errors, from ordering to bedside administration (Franklin et al., 2007; Kaushal, Shojania, & Bates, 2003; Mekhjian, Kumar, Kuehn, & Bentley, 2002).

Approaches to Medication Administration

One of the entry-to-practice mandates for registered nurses (RN) in the province of Ontario is the safe administration of medication (College of Nurses of Ontario, 2014). In 2017, The College of Nurses of Ontario (CNO) heavily revised the Medication Administration Practice Standard by establishing three key principles of medication management: (a) *authority*; (b) *competence*; and, (c) *safety* (College of Nurses of Ontario, 2017). Of these principles, *safety* is central to the application of medication management practices. According to the Medication Administration Practice Standard, RNs are only able to perform the administration of prescribed medications once a medication order has been evaluated against three specific requirements; insomuch as the medication order is required to be: “clear, complete, and appropriate” (College of Nurses of Ontario, 2017, p. 3). While the CNO outlines these requirements, there are minimal applicable definitions of their use within the Practice Standard.

Prior to the development of this principles-based *clear, complete,* and *appropriate* approach to medication administration, a heuristic of five to nine *rights* (i.e., right patient, right medication, right route, right time, right dose, right documentation, right action, right form, right response, etc.) was commonly used to guide best practice in medication administration (Anest, 2013; Booth et al., 2017c; Krautscheid, Orton, Chorpenning, & Ryerson, 2011; Novak, Holden, Anders, Hong, & Karsh, 2013). With the increased use of eMAR systems in healthcare environments (Kutney-Lee & Kelly, 2011), questions have been raised about the transferability of these medication *rights* to the process of electronic medication administration (Novak et al., 2013). As such, the shift to a principles-based approach for medication administration (i.e., *clear*, *complete*, and *appropriate)* has been advocated by Hallaran, McNabb, and Anderson (2015) in order to “achieve a balance between broad applicability and usefulness…[that] can be applied to various practice settings, nursing roles, and medication practices” (p. 46-7), including administration processes involving eMAR systems.

eMAR and Nursing Education

For undergraduate nursing programs, the shift toward educating nursing students to medication administration processes underpinned by eMAR technology has been a recent occurrence. Historically, nursing programs have primarily educated students to non-digital medication administration approaches which were underpinned by processes using handwritten documentation on paper records (Krautscheid et al., 2011; Lucas, 2010; Warren & Connors, 2007). Recently, in an attempt to evolve professional practice education, undergraduate nursing programs have begun to embed medication administration processes involving eMAR systems into simulated education (Bowers et al., 2011). However, implementation and diffusion of eMAR systems within nursing education has been far slower than external clinical partners (e.g., hospitals, clinics, long-term care facilities, etc.)(Herbert & Connors, 2016). One significant barrier faced by many schools of nursing regarding implementation of eMAR systems into education has been attributed to the excessive costs related to the procurement, maintenance, and support of an eMAR system that also fits the pedagogical requirements of simulation (Lucas, 2010; Warren & Connors, 2007). For instance, it has been estimated that costs associated with integration of an educational eMAR system for clinical simulation can range from $3,000 to over $30,000 (Chung & Cho, 2017; Lucas, 2010). Given the significant infrastructure (e.g., hardware, computer technology, etc.) and potential licensing costs and maintenance fees, it has been found that eMAR expenses can quickly accumulate (Booth et al., 2017c; Herbert & Connors, 2016; Lucas, 2010).

In response to these challenges, some academic institutions have turned to partnerships with technology companies and teaching hospitals to help mitigate the individual responsibility in acquiring eMAR technologies for teaching (Anest, 2013; Bowers et al., 2011; Herbert & Connors, 2016; Lucas, 2010). However, not all academic facilities currently have these funding or partnership options available to them, and subsequently have undertaken other approaches to develop and implement eMAR technology within educational pedagogy. In the published literature, there are examples of academic institutions developing *home grow*n (i.e., developed locally by the academic institution) eMAR systems at a fraction of the cost of a commercially available platform (Booth et al., 2017a; Bowling, 2016; Herbert & Connors, 2016; Rubbelke, Keenan, & Haycraft, 2014).

Advancing Understanding of Medication Administration

Teaching-learning strategies related to eMAR administration in undergraduate nursing education have recently begun to be reported in the literature. While no singular set of best practices for eMAR education have been developed or established, a number of researchers have published their findings related to eMAR use in undergraduate education and related teaching-learning suggestions (Angel, Friedman, & Friedman, 2016; Booth et al., 2017b; Booth et al., 2017d; Hawkins et al., 2017; Jenkins, Eide, Smart, & Wintersteen-Arleth, 2018; Novak et al., 2013). For instance, Canadian researchers (Booth et al., 2017b) have used various competencies and professional standards advocated by regulatory and professional bodies to generate insights related to the process of eMAR administration in student education (Canadian Association of Schools of Nursing & Canada Health Infoway, 2013, 2015). Contemporary exploration in this domain has also outlined that the shift from paper-based to eMAR administration processes have highlighted how explicit use of a medication *rights* (i.e., right medication, right time, right dose, etc.) approach to administration is at times incompatible with workflow mandated by eMAR systems (Booth et al., 2017a; Booth et al., 2017c; Novak et al., 2013). Finally, other researchers have described medication administration with eMAR systems as being disruptive to established workflows and problem-solving approaches used by nurses (Chung & Cho, 2017; Hawkins et al., 2017; Jenkins et al., 2018; McComas, Riingen, & Chae Kim, 2014; Staggers et al., 2015).

While the primary purpose of eMAR systems is to improve patient safety, these forms of technology have been almost universally found to negatively influence some aspect of the nurses' efficiency in the medication administration process (Franklin et al., 2007; Hawkins et al., 2017; McComas et al., 2014; Whitt, Eden, Merrill, & Hughes, 2017). Currently lacking in the research literature are examinations exploring how nurses balance the need to ensure safety, while maintaining some level of pragmatic efficiency in the larger eMAR administration process. Due to this research gap, it was deemed worthy to explore the decision-making of nursing students and how they strike a balance (i.e. optimize) between medication administration *best practice* and aspects related to their *efficiency* in the eMAR administration process.

Given increasing adoption of eMAR technologies in all areas of clinical practice, it is vital that nursing educators obtain a deeper sense of how students undertake decision-making with eMAR technology in the medication administration process. Surprisingly, there has been little work conducted to date exploring how nursing students make decisions when using eMAR technology. Of the research that does exist, much of this work has been based on educators' personal experience or reflections with these technologies (Chung & Cho, 2017), rather than best practices grounded in research or theory. Therefore, it is essential that further research exploring nursing students' decision-making processes using eMAR technology be conducted in order to assist in the understanding of optimal medication management as it pertains to best practice principles.

Statement of Study Purpose

The purpose of this inquiry is to explore the decision-making processes exhibited by nursing students when creating relationships with an eMAR system for medication administration. This study will be underpinned by the theoretical lens of cooperative interdependence found in Game Theory. Specifically, the *Snowdrift Game* (Doebeli & Hauert, 2005) will serve as the interactive context used to analyze the cooperative interdependence of an eMAR system and its respective user (i.e., nursing student), in order to describe the decision-making paradigm created by students and the eMAR system. The findings of this study will help develop the central elements of successful optimization of the eMAR administration process; assist toward influencing the overall purpose of eMAR use within nursing education; and, expand upon the growing body of best practice principles related to medication administration technology.

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CHAPTER TWO

This chapter will provide a detailed description of background information and literature necessary to understand both the context and rationale of this research study. The theoretical lens, study design, and research methods used in this study will also be discussed in depth. Finally, findings emerging from the analysis will be provided and discussed within the context of the study.

Background

Optimization

As defined by the Merriam-Webster Dictionary, *optimization* is "an act, process, or methodology of making something (such as a design, system, or decision) as fully perfect, functional, or effective as possible" (Optimization, n.d., para. 1). With the increasing integration of electronic medication administration record (eMAR) technology in undergraduate nursing education and the subsequent changes in the College of Nurses' of Ontario (CNO) standards of medication administration to a principles-based approach of "clear, complete, and appropriate" (College of Nurses of Ontario, 2017, p. 3), care must be taken to develop and refine teaching-learning methods for eMAR administration that advocate for both safety, but also support pragmatic levels of process efficiency for the nurse. As described previously, while patient safety remains the paramount rationale for the use of eMAR in medication administration, eMAR systems have been found to influence the efficiency of nurses in varied and nuanced fashions (Franklin, O'Grady, Donyai, Jacklin, & Barber, 2007; Hawkins, Nickman, & Morse, 2017; Whitt, Eden, Merrill, & Hughes, 2017). While the evidence of reduced medication errors has been well documented as a result of eMAR usage, there has also been substantial work exploring how these eMAR safety benefits are only realized if nurses use the system exactly as intended by its designers and developers (Chaudhry et al., 2019; Mcbee, 2019; Staggers, Iribarren, Guo, & Weir, 2015). Due to the complex and chaotic nature of modern-day nursing practice, nurses commonly develop work-arounds to expedite or optimize processes deemed too cumbersome or time consuming to complete as originally intended by system designers (Vogelsmeier, Halbesleben, & Scott-Cawiezell, 2008). To date, deeper understandings related to the decision-making processes undertaken by nurses using eMAR systems has not been extensively examined by nursing researchers. Further, there is currently almost nothing known about how nurses make decisions throughout the eMAR administration process, and whether optimization between elements of medication safety and eMAR administration process efficiency are undertaken, valued, or even considered.

Theoretical Lens

Game Theory

Game Theory (GT) can be roughly defined as the theoretical construct, found within applied mathematics, used to examine decision-making processes (McCain, 2013). Within GT there are several models, expressed as *games*, that are used to delineate the different types of interaction, both cooperative and competitive that occur between parties. It is of importance to note that the use of terms like *game*, *player*, or *experimental game* do not reflect the traditional understanding of games as forms of entertainment or amusement (Game, n.d., entry 1). GT, as mentioned above, relates to the interplay of participants when addressing the decision-making structure of cooperative or uncooperative engagement (McCain, 2013).

Based on this understanding of this high-level framework of GT, general definitions of *game* and *experimental game/model* need to be defined. *Experimental game/model* refers to the type of model and mathematical algorithm used within GT based on the circumstances of the interaction. These are typically generated from the ideas of *zero-sum* and *non-zero-sum* outcomes. *Zero-sum models* are colloquially known as ‘win-lose’ situations (Marco, 2001) and classically involve competitive moves generated with the intention of achieving greater payout (outcome) than a corresponding opponent can generate. In these zero-sum models, players generally compete for portions of a finite denominator of payout (Marco, 2001); insomuch as, players work cooperatively or noncooperatively to increase their own net outcome relative to the finite denominator of potential payout. *Non-zero-sum models* differ from zero-sum games. Rather than dividing a finite payout amongst players (i.e., sum-zero model), players actively attempt to grow the actual size of the payout potential in its entirety (Marco, 2001). These experimental games were described in detail by Nash (1950) resulting in their later entitlement as the *Nash Equilibria* or *Nash’s Equilibrium* (Myerson, 1999). Nash’s Equilibrium is reached when each player employs the same strategy resulting in responses based on the estimated best response of the other (Hamilton & McCain, 2009; McCabe, Rassenti, & Smith, 1996).

Since its application outside of theoretical and applied mathematics, GT has been applied to variety of disciplines including evolutionary theory, theoretical and mathematical biology, behavioural psychology, management research, and artificial intelligence (Chalkiadakis, Elkind, & Wooldridge, 2011; Colman, 2003; McCain, 2013). Within healthcare, GT models have been used to explore the proliferation of metastatic cancer cells; the development of trust in the general practitioner/patient relationship; enhance the training of medical students; and, to guide the organization and management of emergency department resources and staffing (Blake & Carroll, 2016; Dowd, 2003; Marco, 2001; Tarrant, Dixon-woods, Colman, & Stokes, 2010; Wu, Chen, & Wu, 2017)

In order to operationalize GT as a lens from which to explore decision-making by nursing students using eMAR in light of medication safety and process optimization, a cooperative game known as the Snowdrift Game (Doebeli & Hauert, 2005) will be used to both conceptualize and analyze the cooperative interdependence of an eMAR system and its respective user (i.e., nursing student).

Snowdrift Game (SG)

Cooperative GT games such as Snowdrift Game (SG) rely on the *cooperation* or *defection* of each player toward a common goal (Chalkiadakis, Elkind, & Wooldridge, 2012). Kümmerli et al. (2007) explains the SG by describing the hypothetical scenario of two Drivers (i.e., Driver A; Driver B) who become trapped by a large snowdrift directly opposite each other (Kümmerli et al., 2007). At this initial point in the scenario, each Driver possesses two options: (a) remain in their vehicle and not attempt to shovel their vehicle free of snow (i.e., defect); or, (b) to shovel the snow in an attempt to escape the snowdrift (i.e., cooperate). The success of this effort (i.e., to escape from the snowdrift) is conditional based on the decisions of both Drivers. If Driver A shovels but Driver B does not, the best outcome is taken by Driver B who does not have to do any work but is eventually freed of the snowdrift because of Driver A's efforts. However, if both Drivers A and B do not shovel, neither driver is able to escape from the snowdrift. Therefore, it is in the best interest that both Drivers shovel (cooperate) to avoid a no-win scenario, where both drivers fail to escape the snowdrift. In this scenario, cooperation represents the best outcome for both parties (i.e., both Drivers A and B shovel). Figure 1 demonstrates this relationship (Doebeli & Hauert, 2005).

Snowdrift Game	Cooperate	Defect
Payoff to Cooperate	b-c/2	b-c
Payoff to Defect	b	0

Figure 1. Traditional Payoff Matrix, b=benefit, c=cost, where b>c>0

In relation to the task of eMAR administration by nurses, the SG model provides a usable taxonomy from which to map the various cooperate or defective interactions between players (i.e., nursing student and eMAR system). Further, the SG model can help to define the typology of decision-making involved in the interaction between the nursing student and eMAR system, and whether any level of cooperation (i.e., optimization) exists between these players (i.e., nursing student; eMAR) in relation to two specific dimensions of interest: (a) medication administration best practice (BP); and, (b) efficiency in the administration process. Figure 2 outlines the payoff matrix as modified and used in this work.

Interaction		eMAR	
		Cooperate	Defect
Nursing Student	Cooperate	BP and efficiency balance	BP heavy
	Defect	Efficiency heavy	No relationship

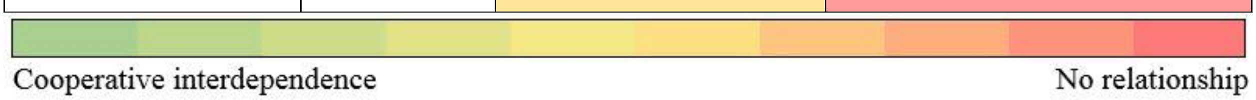

Figure 2.Modified Payoff Matrix

Theoretical Lens Rationale

While this study uses a relatively novel application of GT as its theoretical lens, examinations exploring the dynamic relationship between *humans* and *technology* is extensive. Within nursing and healthcare, there have been multiple frameworks and theories put forward to help describe or explain the nuanced relationship between humans and technology in healthcare actions – most notably, *socio-technical* theories which seek to explore the relationship between humans and technology (Berg, Aarts, & van der Lei, 2003; Lovett, Holden, Anders, Hong, & Karsh, 2013; Sittig & Singh, 2010). Although these frameworks and theories tend to lay specific parameters as to what constitutes *human* or *technology*, all socio-technical approaches suggest that non-human entities like an eMAR system need to be conceptualized as an *actor* that can generate action and shape activities of other actors in the surrounding environment (Walsham, 1997). While differences between the role of the nursing student participants and eMAR system will be described, both players (i.e., nursing student; eMAR system) will be viewed as equal, active players in the formation of cooperative relationships in the larger medication administration process.

One oldest iterations of socio-technical theory that conceptually aligns well with GT is Actor-Network Theory (ANT). While initially developed in the 1980s (Walsham, 1997), ANT has undoubtably helped to pave the way for other socio-technical theories to emerge. Specifically, ANT helps a researcher discuss the social construct of technology, not how technology is used within a social construct (Walsham, 1997). ANT describes the interaction of the technical elements and the social elements as inseparable where both actors are in a given relationship. As stated by Walsham, "Actor-Network Theory examine[s] the motivation and actions of groups of actors who form elements, linked by associations, of heterogeneous networks of aligned interests" (p. 469). Subsequently, ANT allows for the expansion of the role of technology to become an active participant (i.e., player) in the formation of cooperative relationships with other players. Drawing from the ontological directive provided by ANT to allow for a reality where humans and technology can co-exist and possess potentially equal importance in a relationship, using GT as the theoretical lens to operationalize this study was deemed appropriate.

Literature Review

An extensive literature review was completed to ensure an appropriate understanding of the concepts presented in this study. Databases consulted included: The Cumulative Index of Nursing and Allied Health Literature (CINAHL), Scopus, PubMed, and Google Scholar. Search terms used in various combinations included: *electronic medication administration, nursing students, Game Theory, Snowdrift Game, Cooperative Game Theory, optimization,* and *safety.*

Boolean modifiers were used in conjunction with these search terms to explore their various combinations (Polit & Beck, 2017). Additionally, articles were combed for reference titles congruent with the research question (Arksey & O'Malley, 2005). Being cognizant of the expansive timeline associated with this study, including concepts originating decades ago (i.e., GT) to relatively recent technological advancements (e.g., eMAR), no temporal limitations on peer-reviewed literature were set. Unpublished manuscripts including theses and dissertations were also included. Following a search of the above terms, study abstracts were examined for their relevance to the research question and decisions regarding the associated studies' eligibility were decided (Colquhoun et al., 2014; Levac, Colquhoun, & O'Brien, 2010).

Upon the completion of the initial literature search and the subsequent abstract screening process, 22 articles were included in this review. Of these 22 articles, 18 primarily involved eMAR or electronic health record technologies, while the other four focused on the concept of GT. The selected studies ranged from 2002 to 2019 and varied significantly in terms of study design. Using a scoping review methodology (Arksey & O'Malley, 2005; Levac et al., 2010) narrative insights were drawn and summarized from the 22 articles and organized into three major thematic categories: (a) cooperation in Game Theory; (b) increased patient safety; and, (c) eMAR technology use in undergraduate nursing education.

Cooperation in Game Theory

While traditional iterations of Game Theory hinge on the competitive nature of the decision-making process, there is a subset of GT that relies on cooperative interaction. In these such cases, different formations of coalitions are better able to provide net benefit to all players involved in the game. For instance, there are a number of specific types of coalitions that cooperative GT can produce that ultimately lead to the greatest payoff for the perceived *fairness* of contribution (Chalkiadakis et al., 2012). This differs from other iterations of GT, where players commonly seek to protect themselves at the potential expense of the other players (i.e., Prisoner's Dilemma), resulting in players experiencing worse outcomes than if they had cooperated with each other (Doebeli & Hauert, 2005). Overall, it has been found that cooperation occurs more frequently in the application of SG than in other GT games (Kümmerli et al., 2007). This further justifies the application of SG to situations where forming a coalition between players generates the most preferable or successful outcome. Successful outcomes are also seen in coalition situations involving human and non-human entities (Chalkiadakis et al., 2012). In 2013, Démuth discussed the application of GT to non-living systems possessing machine learning and artificial intelligence, which can mimic the problem-solving abilities of humans. Démuth (2013) surmised that predictable, algorithmic iterations of non-living systems have the ability to show cooperative intention towards a common goal as long as rational choices are taken by all parties.

Increased Patient Safety

Increased patient safety was a second thematic category that emerged from the literature review. For instance, a study from 2003 examined the overall reduction in medication errors with the use of computerized provider order entry (CPOE) systems as well as examined some differences between commercially available and homegrown systems (Kaushal, Shojania, & Bates, 2003). In this systematic review, the authors found 12 studies meeting their search criteria, that demonstrated significant reductions in serious medication error rates; of these 12, only 2 involved non-commercial or homegrown systems. Unsurprising, the authors found that commercially developed systems were more expensive than those internally developed (Kaushal et al., 2003).

Staggers, Kobus, and Brown (2007) discussed various design principles from large private vendors to determine which elements could be used to create effective eMAR systems. In their study the researchers created their own eMAR system and evaluated with 20 Navy nurses through semi-structured interviews. From the findings of the study, the researchers concluded that the importance of attending to the user-interface experience (i.e., how a user interacts with the text and graphics of the system) was grossly underestimated, due to the inherent complexity of an interdisciplinary eMAR system, and the lack of documented literature on appropriate eMAR design (Staggers, Kobus, & Brown, 2007).

A quasi-experimental, time-series analysis completed by Franklin et al. (2007) conducted in a 28-bed medical-surgical ward of a teaching hospital examined factors of patient safety, both pre- and post- implementation of a closed loop medication administration system. The authors determined that two in every 100 prescribing errors were eliminated with the use of CPOE;

further, that administration errors could be significantly reduced when combined with eMAR use (Franklin et al., 2007).

Kutney-Lee and Kelly (2011) conducted a study examining the combined safety effects of CPOE and eMAR use. In their study, nurse leaders were highlighted as being integral in the successful implementation and improved efficiency that these systems provided (Kutney-Lee & Kelly, 2011). Their study examined the responses from 16,352 nurses in 316 hospitals in the US regarding the staff nurses' perceptions on various quality of care and patient safety indicators. The authors discovered that having a basic electronic health record with assistive decision-making capabilities was associated with nurse assessed positive patient safety outcomes in six of the seven outcomes studied (Kutney-Lee & Kelly, 2011). As such, Kutney-Lee and Kelly (2011) concluded that nurse leaders possess a unique and important position in the implementation, adoption, and uptake of electronic health system success and subsequent patient safety outcomes.

A secondary analysis of two barcode medication administration studies completed by Novak, Holden, Anders, Hong, and Karsh (2013) examined the collision of work processes that occurred during and after the implementation of a CPOE/eMAR technology. They described these "collisions" (p.e332) as the clash between the CPOE/eMAR technology system and various clinical practice elements, resulting in the adaptation of work processes that may negate the positive patient safety outcomes associated with CPOE/eMAR technology (Novak, Holden, Anders, Hong, & Karsh, 2013). The researchers discussed the need to consider the various unintended consequences of such changes to clinical practice, including complex issues related to the strict interpretation of the *Medication Rights* of medication administration in CPOE/eMAR systems, and the work-arounds or adaptations that can influence patient safety in potentially negative ways (Novak et al., 2013).

San et al. (2012) completed a systematic review of six quantitative studies exploring the factors that affect nurses' use of eMAR technologies. The authors reported three major factors related to nurses' use of eMAR systems: *system-related factor, user-related factors*, and *organizational factors* (San, Lin, & Fai, 2012). Three high-level recommendations are provided to assist in improving nurse use of eMAR technologies, including: (a) the need for institutions to accommodate the needs of the users; (b) to adequately prepare and train users to the eMAR system; and, (c) the creation of supportive work cultures, to assist with proper implementation and adoption of eMAR systems and their safety features (San et al., 2012).

Similar to San et al. (2012), in a literature review McBee (2019) explored the evidence related to how nurse workarounds with eMAR technologies can influence patient safety and quality of care. After examination of the included articles, the author identified a number of important considerations related to contemporary use of eMAR technologies. One important insight arising from McBee (2019) was the current "lack of evidence-based standardization in the planning, implementation, and sustainability of BCMA [bar-code medication administration]" (McBee, 2019, p. 2). From the review, McBee (2019) concluded that in order for eMAR technologies (i.e., BCMA) to be successful in positively impacting patient safety and quality of care, organizations need to leverage both the safety features afforded by eMAR technology, but also to carefully consider the operational processes necessary to sustain this type of technology in clinical practice.

A microanalysis arising from a larger ethnographic study completed by Hawkins, Nickman, and Morse (2017) explored the interdisciplinary nature of medication management from ordering practitioner to administrating nurse. The authors described six steps performed by different members of the healthcare team that each required safety checks as a way to minimize the potential of medication errors (Hawkins et al., 2017). However, despite the organizational structure that allowed for numerous opportunities for safety assessments, the authors identified the importance of workplace culture and socialization amongst practitioners as a vitally important factor toward safe medication management (Hawkins et al., 2017). Hawkins et al. (2017) concluded that safe medication management practices heavily relies upon the culture and context of the work environment in which the electronic system exists.

eMAR Technology Use in Undergraduate Nursing Education

In 2007, Warren and Connors published an opinion piece in *Nursing Outlook* exploring the transformative nature of technology in nursing education. The authors discussed the various governing bodies within the United States that were calling for the meaningful integration of electronic systems within the broad healthcare environment. Subsequently, the necessity of incorporating these technologies into nursing education was also discussed. The authors used an example of a 2001 project that successfully implemented an electronic health record into three undergraduate nursing programs to support the call for implementation (Warren & Connors, 2007). It was identified that this project increased students' confidence and critical thinking abilities in medication administration as well as begin to appreciate the "power of the clinical information system" (Warren & Connors, 2007, p. 59).

In response to these calls for meaningful implementation of electronic systems in nursing education, many challenges related to their adoption were identified. One of the identified challenges for nursing educators was that of the financial costs associated with the implementation of eMAR technologies. Some authors have explored the need for collaboration between clinical placements and academic settings to reduce the financial burden. For example, Lucas (2010) published a commentary paper regarding the partnership of their undergraduate nursing program and a local healthcare organization. In this project, nursing students were given free access to the eMAR training system used by the local healthcare organization that students would later use during future clinical placements (Lucas, 2010).

A study published in 2011 explored the experiences of nursing students related to their medication administration education (Krautscheid, Orton, Chorpenning, & Ryerson, 2011). This qualitative phenomenological study aimed to understand which teaching and learning strategies students believed to be effective to prepare them for medication administration in clinical environments (Krautscheid et al., 2011). A finding arising from the study was that participants voiced there was a need for educators to use relevant technologies in nursing education (Krautscheid et al., 2011). Participants in the study discussed the presence of electronic systems (including eMARs) but felt that their nursing education had not adequately prepared them to use these kinds of clinical technologies.

Similar to Krautscheid et al. (2011), Bowers et al. (2011) completed a study examining eMAR use by undergarduate nursing students, by partnering with a healthcare organization to obtain access to a commercially available eMAR technology (Bowers et al., 2011). Over a 12-month period, nursing students participated in three courses designed around the introduction and meaningful use of the eMAR system. After their participation, a survey was completed by the students to evaluate the system and the subsequent learning experience. In general, students felt prepared for clinical practices using the eMAR system after completion of the three training courses.

Other researchers have explored the development of homegrown systems as a mechanism to mitigate high costs associated with purchasing an established electronic platform. In a study from 2014, faculty developed an electronic health record using an open source application to mimic the data entry functions of a commercially available technology (Rubbelke, Keenan, & Haycraft, 2014). The authors of this study identified several advantages to developing a homegrown system, including the ease of making modification to the electronic record without incurring licensing or maintenance fees commonly charged by vendors of commercially available systems (Rubbelke et al., 2014).

Similar to Rubbelke et al. (2014), two Canadian reports evaluated elements of a homegrown eMAR system for undergraduate nursing education (Booth, Sinclair, Brennan, & Strudwick, 2017a; Booth et al., 2017c). In this mixed-methods quality improvement study, 25 nursing students were observed administering medications using the eMAR system in clinical simulation, then interviewed related to their use of the system. The researchers discovered that the majority of medication errors generated by students occurred during the patient and medication verification stage, physical scanning and manipulation of the barcode scanner, and physical administration of the medication (Booth et al., 2017c). Based on their findings, the authors suggested the need for medication administration teaching-learning opportunities to be reconceptualized in light of electronic administration systems that disrupted traditional teaching-learning approaches to medication administration in nursing education (Booth et al., 2017c).

Research Question

In order to examine the decision-making processes exhibited by nursing students using eMAR technology in simulated practice, the following research question was explored in this study: How do nursing students generate optimized medication administration processes using eMAR technology in simulated clinical practice?

Methods

Context

Simulated Medication Administration Record Technology (SMART) Overview

The Simulated Medication Administration Record Technology (SMART) eMAR program was developed at a large, urban university in south-western Ontario (Canada) in late 2015 in response to a need to implement an eMAR system for simulated clinical education. As of Fall 2016, the SMART eMAR was fully integrated into the simulated clinical education activities of the undergraduate program at this university. The SMART eMAR was the eMAR system used in this research study.

While a simulated eMAR system, the SMART eMAR provides similar functionalities of a commercially available eMAR technology. These included colour-coded prompts for correct/incorrect barcode scanning, automated time-stamping, and eventually ‘pop-up’ windows for indication of potential medication interactions. Additionally, there are multiple ‘self-populating’ elements that allow users to qualify their medication administration including drop-down comment selection, a signature field, and an area for free text allowing the nursing students to add additional information to the record as they deem fit. Visually, the program was designed to have a similar user interface to that of a commercial eMAR used within the university’s municipality. Through the customization of patients and medications in the record and the use of retail-grade 2D barcode scanners, the SMART eMAR was able to effectively simulate closed-loop medication administration within the simulated scenarios completed in the clinical simulation suite at the university. Further technical details related to the SMART eMAR and its development are published elsewhere (Booth et al., 2017a).

‘Best Practice’ Medication Administration Using SMART eMAR

With the changes to the CNO’s (2017) Medication Administration practice standards to that of a principles-based framework (i.e., “clear, complete, and appropriate”) (College of Nurses of Ontario, 2017), work was conducted by Ontarian nursing researchers to map new best practices related to eMAR administration (Booth et al., 2017b). Figure 3 denotes the published best practice workflow and process related to medication administration using eMAR technology, underpinned by a principles-based approach as advocated by College of Nurses of Ontario (2017). This published workflow of eMAR administration was used as the medication administration process standard in this research study. Therefore, all future discussion of medication administration best practices were drawn from the workflow steps as visualized in Figure 3.

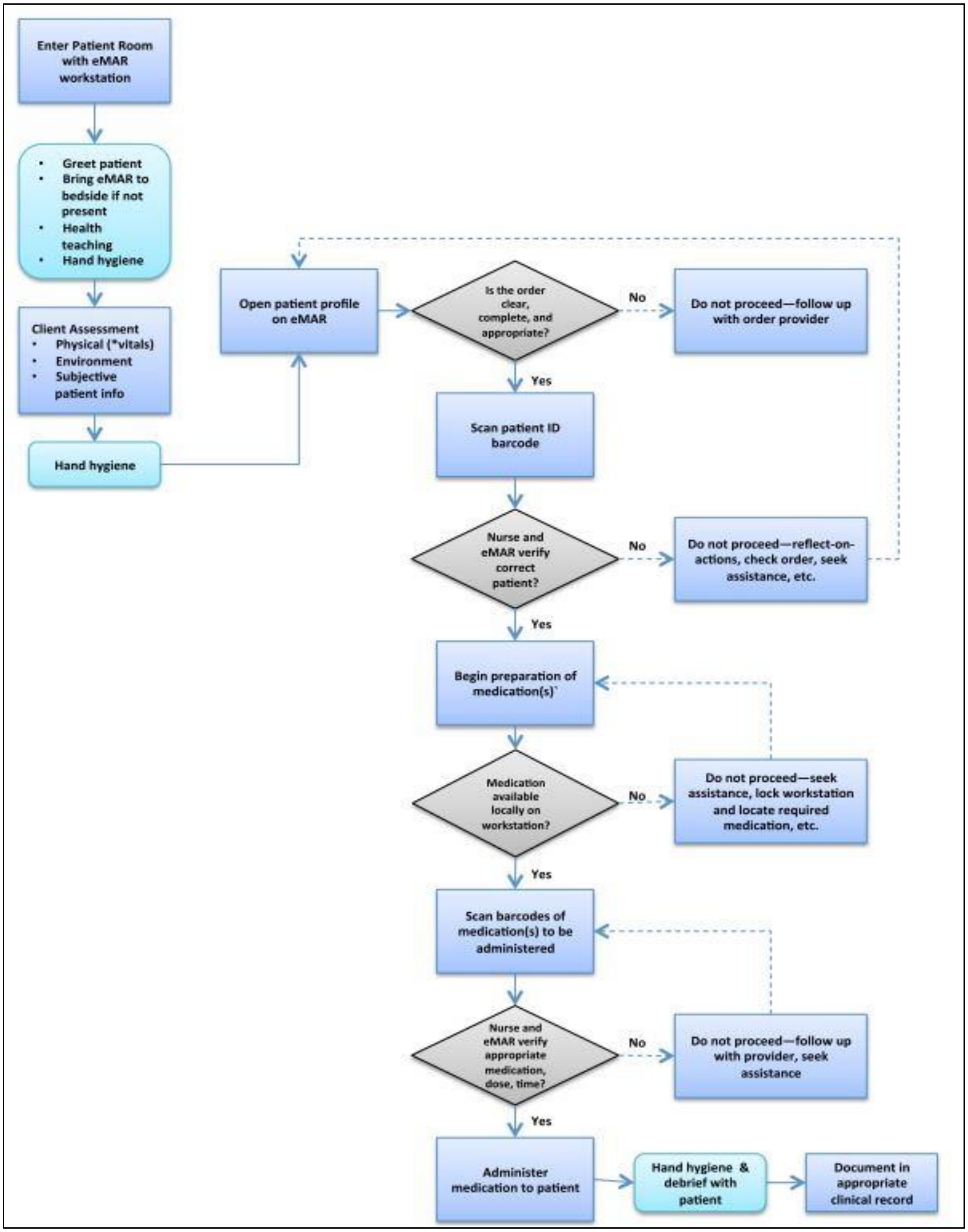

Figure 3 Electronic medication administration workflow

Study Design and Process

This qualitative descriptive study used a series of five researcher-developed medication administration scenarios to elicit data related to nursing students' decision-making regarding eMAR administration. Participant observation is a commonly used method in qualitative research and has been utilized in many research traditions such as ethnography, Grounded Theory, and phenomenology (Polit & Beck, 2017). Within engineering and other research involving human-technical relationships, historically empiric inquiry methodologies tended to favour quantitative study designs and the subsequent analytic techniques used to evaluate findings. However, more recently research methodologies in this domain have begun to encourage the use of qualitative methodologies to provide a deeper understanding of, "the awkward intersection of machine and human capabilities" (Seaman, 2008, p. 35). In particular, participant observation and interviewing have been described as useful methods for computer engineering researchers engaged in the education process (Seaman, 2008). In this study, participant observation and coding of observation and interview datum was undertaken (and further described in the Data Collection and Analysis section). To derive meaning from observational and interview datum, qualitative descriptions of each participant and their decision-making, mapped to a GT payoff matrix, was generated through in depth readings and reflections of this datum. While this study used directed content analysis method (Hsieh & Shannon, 2005) to help develop findings from datum, due to the step-wise and pre-developed scenario-based nature of this study, the analysis approach required to synthesize findings in this study reads and presents somewhat differently than other classical qualitative research in nursing whereby themes are derived mainly from interpretive, qualitative reduction approaches of naturalistic narrative or observational data. Further description of the sample, setting, medication administration scenarios/study process, data collection, and analysis are provided in the following sections.

Sample and Setting

Due to the nature of the medication administration scenarios, potential study participants needed to be students in either the undergraduate nursing program or graduate nursing program at the local university where data was collected. Further, all participants needed to have had experience with the SMART eMAR from previous educational activities. After recruitment from both undergraduate and graduate nursing programs, a total of four participants (N=4) agreed to participant in the study. All recruited participants were female, ranging from 21 to 22 years of age. Participants ranged in their academic trajectory, ranging from having only recently completed their simulated medication administration as part of their 2nd / 3rd year education with limited clinical experience, to near completion of their BScN degree. As a result of these variations in academic progression, participants potentially experienced a hybridized education regarding the CNOs guidelines related to medication administration. As the CNOs standards changed in 2017 (College of Nurses of Ontario, 2017), nursing students beginning their studies in 2015 (4th year students nearing completion of their education at the time of data collection) may have experienced the previous *rights* heuristic in their junior years of nursing education. However, at the institution where this study was conducted, medication administration techniques are taught in the second year of the nursing program. As such, all participants in this study should have been formally educated using the principles-based approach of *clear, complete, and appropriate* for their medication management education.

Students from the desired population were invited to participate in this study via presentations made during class time. Researcher contact information was provided for those interested in participation. Sample size for this project was based on principles of achieving thematic saturation while maintaining restrictions related to cost and the depth of information received from each participant (Polit & Beck, 2017). Within both nursing research and software engineering research, thematic saturation can occur with fewer participants when the depth of information obtained is representative of both the population and the "smallest important subgroup" (Kitchenham & Pfleeger, 2008, p. 87). Therefore, sample size within qualitative research in computer engineering and other related research domains that explore human-technical relationships has been historically noted to be characteristically small (Dyba, Prikladnicki, Ronkko, Seaman, & Sillito, 2011).

To conduct the study, a simulated clinical environment was generated that consisted of the eMAR, barcode scanner, and a patient identification band. These were mounted on a workstation-on-wheels cart that also housed a selection of both correct and incorrect medications for the participant to choose from during the scenarios. To assist the participant in the scenarios, a nursing drug guide was also provided.

Medication Administration Scenarios and Study Process

Five unique medication administration scenarios were generated by the researcher to explore the decision-making processes of nursing students. These scenarios were built upon the CNO's requirements for medication administration of *clear, complete,* and *appropriate* (College of Nurses of Ontario, 2017, p. 3). Further, each medication administration scenario possessed two instances of interaction between the nursing student and the eMAR system. These two instances of interaction included: (a) Patient Identification Verification; and, (b) Medication Verification. While not formally validated, these scenarios were reviewed by fellow graduate nursing students for their accuracy of representation and clarity. Adjustments were made accordingly. Each scenario was printed on paper and presented to the nursing student participant. The researcher asked the participant to read the scenario and complete the described medication administration task. Depending on the actions during the scenario, each player (i.e., eMAR system; nursing student) had the potential to cooperate or defect with the other player in the generation of an outcome.

The five medication administration scenarios are described below:

1. Challenging the CNO's Concept of *Clear*: This scenario examined the CNO's concept of "Clear". An electronic order was provided where in place of fully written instructions, commonly used, but not legally representative, acronyms were used. This medication order read: "Docusate Sodium 100 mg, PO, BID". This order would not be considered "clear" as it does not fully explain the administration instructions.

2. Challenging the CNO's Concept of *Complete*: This scenario examined the concept of "Complete". An electronic order was provided where one of the elements necessary to administer the medication properly is missing. This medication order read: "Metoprolol 25, orally at 0800h". This order would not be considered complete as it is missing the unit of measurement for the medication, in this case milligrams (mg).
3. Challenging the CNO's Concept of *Appropriate:* This scenario challenged the CNO's concept of "Appropriate". An electronic order was provided that satisfied both the first two order criteria (Clear and Complete). The medication to be given affects the blood pressure of the patient. The student received the medication order and was also provided with a piece of paper that stated a colleague completed a set of vitals on the patient for the participant so they "wouldn't have to". The blood pressure in this set of vitals was

borderline normal. In this scenario the order would not be considered “appropriate” if the patient’s blood pressure was indeed low (upon reassessment of the patient), or if the participant choose to proceed with the vitals as provided as they did not reflect a time of collection.

4. Challenging the CNO’s Concept of *Complete:* This scenario again challenged the concept of “Complete”. An electronic order was provided where one of the elements necessary to administer the medication properly was be missing. This medication order read: “Metoprolol 50mg at 0800h”. This order would not be considered complete as it is missing the route of administration, in this case orally. Participants were challenged to recognize this omission.

5. Challenging the CNO’s Concept of *Appropriate:* This scenario challenged the CNO’s concept of “Appropriate”. An electronic order was provided that satisfied both first two order criteria (*Clear* and *Complete*). The eMAR has a documented medication given prior to this scenario. This medication has minor contraindications with the medication the participant was requested to give. The eMAR revealed an insulin injection was given 15 minutes prior to the scheduled administration time of Acetylsalicylic Acid (ASA). Once the medication was properly scanned, an alert was produced that there was a potential drug/drug interaction between ASA and insulin. Participants were challenged to: (1) close the window and administer the medication as originally written; (2) stop the administration process and hold the medication; (3) stop the medication administration process, seek clarification, and resume administration; or, (4) stop the administration process, seek clarification, and hold the medication.

Data Collection and Analysis

Data was collected over a course of three months in early 2019. To assist in data collection, a GT matrix was developed for each of the two potential interactions, for each of the five aforementioned scenarios. The GT matrix helped to codify relationships between the participant and eMAR system during data collection. This was achieved based on the participant’s actions related to BP principles and the eMAR efficiencies during the scenarios. These codes helped to illustrate the player relationship created based on either cooperation or defection. Therefore, the following structure will be applied to each participant case in order to maintain consistency of analysis and interpretation of the two primary interactions: (a) Patient Identification; and, (b) Medication Verification.

Data analysis consisted of both observation data and interview data with participants. Observation data arising from participants completing the medication administration scenarios was codified on GT matrices; interview data were analyzed using a directed content analysis approach (Hsieh & Shannon, 2005). Further, interview data was also used to complement and deepen the insights gained from the observation data, as related to specific decisions made during the scenarios by participants. Data was analyzed over a period of four months to ensure sufficient exploration of datum. This study received ethics approval from the Health Sciences Research Ethics Board at Western University, London, Ontario (Appendix A).

Author's Position Statement

The methods used in this study rely heavily on the SMART computer program that was designed and created by the author of this work. Expert consultation was used in its creation and subsequent use in simulated education to ensure accuracy in proper medication administration techniques, as well as reflecting the teaching-learning techniques used by educators at its time of creation. Further information on this process is published elsewhere (Booth et al., 2017a; Booth et al., 2017b). Additionally, the author of this work has participated in research regarding the potential determination of *Best Practice* principles of electronic medication administration, again using the SMART eMAR as the electronic platform (Booth et al., 2017b; Booth et al., 2017c; (Booth et al., 2017d). The methods used in this study were likely potentially influenced by the familiarity of the authors to the SMART system and previous experience using this technology within similar research activities.

Findings

The findings outlined below are divided into cases where each participant represents its own case. Within each case, an analysis of each interaction was completed with detailed descriptions of the participant's actions and decision-making process described and visualized on various GT payoff matrices. To report each participant's findings consistently, each case deconstruction will first begin with a brief description of the participant and their previous experiences with electronic medication administration systems. Second, a detailed deconstruction of the participant and their actions, decision-making processes, and resulting GT relationships will be reported as per each Scenario described in *Medication Administration Scenarios and Study Process* section. Finally, given the large number of potential GT payoff matrices that could be conceivably reported in this study (2 interactions x 5 scenarios x 4 participants = 40 potential matrices), only a selection of matrices that provide formative insights to the decision-making process of each participant will be provided in the Findings section.

Participant 001

Participant 001 self-described as a 22-year-old female who was nearing completion of her undergraduate nursing degree. 001 expressed possessing an advanced knowledge of electronic medication administration record technology. Specifically, 001 stated, "experience using Powerchart" but failed to describe the extent of this experience. *Powerchart* is known as one of the many commercially available eMAR platforms currently used within many local acute care facilities.

Scenario 1: Challenging the CNO's Concept of *Clear*.

Patient Identification Verification

001 was able to correctly scan the patient armband as well as confirm the patient's full name. In doing so, 001 maintained principles of both BP and GT in equal balance where 001 relied on principles of efficiency (i.e., correct scan of patient identification band) and BP (i.e., requiring a minimum of two patient identifiers prior to administering a medication). The interaction between can be demonstrated in a payoff matrix where in cooperation with the eMAR system, 001 chooses to allow the eMAR to verify the patient information while also independently verifying the information as per BP guidelines. Thus, the matrix is balanced regarding the efficiency of the eMAR decision making and their own (Figure 4), the payoff is balanced.

Patient Identification Verification		eMAR	
		Cooperate	Defect
001	Cooperate	**Correct scan and independent verification (i.e. BP**	Incorrect scan and multiple independent verification (i.e. BP heavy)

		and efficiency balance)	
	Defect	Correct Scan and no independent verification (i.e. Efficiency heavy)	Incorrect scan and no independent verification (i.e. no relationship)

Figure 4

Medication Verification

In the second interaction, 001 had the opportunity to again strike a cooperative balance between BP and efficiency. However, this was not the case. During this initial interaction, 001 scanned the medication in an incorrect area of the eMAR. While 001 did later correct this error and scan in the correct cell, this error increased the amount of time spent trying to identify if the medication was correct or not. Once this error was resolved and the medication was scanned in the correct cell, the eMAR returned a green prompt indicating that the medication indeed was correct. Upon seeing this, 001 administered the medication to the simulated patient.

However, the order in question used a short form “PO” to indicate the route of administration. Under the CNO’s concept of *clear* the order ought to have stated “orally” to be considered *clear*. Figure 5 represents the GT relationship created.

Medication Verification		eMAR	
		Cooperate	Defect
001	Cooperate	Correct scan and independent verification (i.e. BP and efficiency balance)	Incorrect scan and multiple independent verification (i.e. BP heavy)
	Defect	**Correct Scan, no independent verification. 001 administered the medication despite the unclear order (i.e. Efficiency heavy)**	Incorrect scan and no independent verification (i.e. no relationship)

Figure 5

Scenario 2: Challenging the CNO’s Concept of *Complete*.

Patient Identification Verification

Again, 001 was able to correctly scan the patient armband as well as confirm the patient's full name. A balanced payoff matrix was again achieved by 001 during this phase of Scenario 2 indicating a balance of BP and efficiency.

Medication Verification

Scenario 2 challenged 001's knowledge and critical evaluation of the CNO's concept of *complete.* The Scenario omitted the unit of measurement for the medication to be administered, a critical component of any *complete* medication order. 001 correctly used the barcode scanner to identify the medication. The eMAR system returned the indication of 'correct medication' and the selected tile turned green. 001 administered the medication to the simulated patient. This administration indicates a heavy reliance on the eMAR and the efficiencies it can offer. However, this is under the assumption that the information initially entered by the provider was correct. 001 did not apply an independent verification of the order as suggested by BP. As such, 001 was unable to strike balance.

Scenario 3: Challenging the CNO's Concept of *Appropriate.*

Patient Identification Verification

001 was provided with a piece of paper reflecting a set of vital signs that were collected by a colleague. 001 correctly matched the patient information on the vital signs with that of both the eMAR and the patient armband. 001 proceed with a correct iteration of scanning and verification of the patient. Thus, a balances payoff matrix was achieved in this interaction.

Medication Verification

This Scenario primarily challenged the CNO's concept of *appropriate*. 001 noted on the provided vital signs assessment that the simulated patient's blood pressure was borderline hypotensive, but that their heart rate was within normal limits. The medication to be administered in this Scenario was used to treat hypertension with a side effect of lowering heart rate as well. 001 correctly identified these elements of the Scenario. Upon this assumption, 001 proceeded to scan and administer the medication. As the eMAR has no way to identify the *appropriateness* of a medication, it returned a 'correct medication' green prompt.

However, 001 neglected to assess the provision of the vital signs themselves. There was no date or time indicated on the measurements. Additionally, a borderline abnormal vital assessment, in this case blood pressure, ought to have been rechecked by the nurse responsible for providing a medication. As such, 001 again demonstrated a heavy acceptance of the eMAR's move of relaying 'correct medication' despite indicators that further verification of BP principles was required. Figure 6 again displays the payoff matrix associated with this interaction.

Medication Verification		eMAR	
		Cooperate	Defect
001	Cooperate	BP and efficiency balance	BP heavy
	Defect	**Efficiency heavy. 001 did not complete elements associated with independent verification of BP principles**	No relationship

Figure 6

Scenario 4: Challenging the CNO's Concept of *Complete*.

Patient Identification Verification

001 was able to achieve a cooperative balance between the eMAR and properties of BP for the identification of the patient in Scenario 4. Correct scanning and independent verification were both completed. This again represented a balance payoff.

Medication Verification

001 omitted the route of administration for the medication in question, representing a medication order that did not satisfy the element of *complete* under CNO guidelines. 001 correctly scanned the medication and assessed the eMAR's return of 'correct medication'. 001 then proceeded to administer the medication. At one point during this verification 001 verbally stated, "tablet form" indicating an assessment of the appropriate route of administration, however this information was not actually provided by the eMAR order. This interaction again indicates a

reliance on the eMAR to have provided the correct assessment of the order. As such, the values of efficiency outweighed the concepts of BP.

Scenario 5: Challenging the CNO's Concept of *Appropriate.*

Patient Identification Verification

As with the previous four Scenarios, 001 was able to balance the efficiencies offered by the eMAR platform with requirements of BP. The correct scan was completed followed by an independent verification of the simulated patient's identifying information (name, patient identification number).

Medication Verification

The final Scenario again challenged 001's understanding of the concept of *appropriateness* under the CNO's standards on medication administration. Whereas in the previous Scenario that challenged the concept of *appropriate*, the medication was required to be held to allow for sufficient investigation into the patient's condition. In this Scenario, the medication was to be administered despite the eMAR prompt. 001 correctly scanned the medication in the corresponding cell of the eMAR. 001 was able to identify that all elements of the order were indeed *clear* and *complete*.

The eMAR then returned a notification of potential interaction between the medication 001 was administering and another medication already given on the eMAR. This flag gave 001 the option to continue with the administration of the medication or cancel the attempt. 001 then consulted the drug guide. 001 was unable to either verify or disprove this interaction warning. 001 then verbalized a need to check the patient's history with these medications and if both medications had been regularly given together. 001 therefore cancelled the prompt and held the medication. Figure 7 demonstrated this relationship as a payoff matrix.

This Scenario challenged 001 to identify that the interaction between the two medications was only suspect if 001 were administered within 15 minutes of each other, as outlined in the provided drug guide. Following this independent verification, 001 ought to have continued with the administration despite the warning from the eMAR system. This interaction demonstrated a heavy reliance on BP to the detriment of efficiency (Figure 7).

Medication Verification		eMAR	
		Cooperate	Defect
001	Cooperate	BP and efficiency balance	**BP heavy. 001 held the administration of the medication based on requiring additional and unnecessary BP checks.**
	Defect	Efficiency heavy	No relationship

Figure 7

Participant 002

Participant 002 was a self-identified 21-year-old female student. 002 had completed high school as her highest educational level and did not express any advanced knowledge of electronic medication administration technology outside of nursing simulation education.

Scenario 1: Challenging the CNO's Concept of *Clear*.

Patient Identification Verification

Similar to 001, 002 was able to correctly scan the patient armband and verify with an additional patient verification. 002 was therefore able to balance the principles of BP and GT (efficiency). In doing so, 002 fulfilled both concepts of BP and efficiency in equal measure. Thus, the payoff for 002's patient identification verification was balanced.

Medication Verification

In the second relationship, 002 was unable to find a cooperative balance between BP and efficiency. While 002 was able to correctly scan the medication and received a "correct medication" notification from the eMAR, 002 proceeded to administer the medication despite the short form of "PO" appearing in the official order. Like 001 in the same relationship and Scenario, 002 administered the oral medication even through the order did not satisfy the CNO's concept of *clear*, relying on the eMAR's efficiencies to the detriment of BP.

Scenario 2: Challenging the CNO's Concept of *Complete*.

Patient Identification Verification

During the patient identification verification phase of Scenario 2, 002 attempted to scan the patient's armband. Unfortunately, this was done in the incorrect location on the eMAR. As such, the system was unable to verify the patient's identification. However, 002 did verbally and physically match the patient's armband to the eMAR as well as confirm the patient's full name. Having completed this, 002 continued to the next phase of Scenario 2. This interaction becomes an example of heavy reliance on BP to the detriment of any efficiencies offered by the eMAR. This therefore represents a payoff matrix where 002 defected from the eMAR but was able to safely verify the patient's identity though extensive BP use (Figure 8). 002 relied completely on BP guidelines where the eMAR was not used as a player.

Patient Identification Verification		eMAR	
		Cooperate	Defect
002	Cooperate	BP and efficiency balance	**BP heavy. 002 chose to defect from any eMAR use relying solely on BP.**
	Defect	Efficiency heavy	No relationship

Figure 8

Medication Verification

002 appeared to have a number of challenges while interacting the eMAR in the second relationship of Scenario 2. This Scenario challenged the participant's knowledge on the CNO's concept of *complete.* At the beginning of this relationship, 002 verbalized the need to "double check" vitals. 002 then scanned the medication for verification in the correct location on the eMAR and verbally re-read the order aloud. However, the order itself was incomplete, as per the CNO's standard, as the unit of measurement for the medication was missing (i.e., mg). The eMAR returned a 'correct medication' indication. 002 assumed that the information on the order was initially correct, even verbalizing the unit of measurement that was not included on the eMAR. 002 administered the medication but neglected to sign off on the eMAR indicating the medication was indeed administered. This interaction indicated a heavy reliance on the eMAR and its efficiencies, therefore no balance was struck as necessary element of BP were neglected.

Scenario 3: Challenging the CNO's Concept of *Appropriate.*

Patient Identification Verification

002 was given a set of vitals, collected by a colleague, at the initiation of this encounter. 002 examined the vitals in great detail. However, despite being told that each Scenario was a new encounter with the patient and a new blank eMAR was provided, 002 did not verify the patient in any way. As such, 002 demonstrated no relationship with the eMAR during this phase. 002 did not rely on the efficiencies of the eMAR nor did 002 follow BP guidelines of appropriate patient identification. This lack of interaction reflects an entirely unbalanced and improper method of administration, thus no balance was achieved (Figure 9).

Patient Identification Verification		eMAR	
		Cooperate	Defect
002	Cooperate	BP and efficiency balance	BP heavy
	Defect	Efficiency heavy	**No relationship was created as 002 did not follow either BP or the efficiencies of the eMAR.**

Figure 9

Medication Verification

This Scenario challenged the CNO's concept of *appropriate*. 002 examined the provided vital signs assessment for an extensive period of time. Again, the medication to be administered in this Scenario was used to treat hypertension with a side effect of lowering heart rate. 002 was able to correctly identify the effect and side effect of this medication. As the eMAR has no way to identify the *appropriateness* of a medication, it returned a 'correct medication' green prompt.

Unlike 001, 002 chose to hold the administration of this medication due to the borderline nature of the patient's blood pressure. 002 verbally stated that she would have recheck the blood pressure and consult with another professional. In this interaction 002 demonstrated balance between BP and efficiency, despite the eMAR returning a 'correct medication' indication 002 maintained the principles of BP requiring more information to continue the administration. While the medication was held, this interaction still reflects an appropriate balance between BP and efficiency as both players acted appropriately while cooperating with each other in the interaction.

Scenario 4: Challenging the CNO's Concept of *Complete.*

Patient Identification Verification

As in Scenario 3, 002 failed to properly identify the patient on the eMAR or using principles of BP. As such, no balance was struck in the GT payoff matrix as no relationship was entered at all.

Medication Verification

Scenario 4 again challenged the CNO concept of *complete.* This Scenario omitted the route of administration for the medication. 002 correctly scanned the medication and assessed the eMAR's return of 'correct medication'. However, 002 then made the decision to withhold the medication based on the Scenario stating, "vital sign stable", not based on the lack of clarity in the actual order. While every Scenario, except number 3, stated this in the introduction, 002 only took this action here. In this interaction, 002 was unable to balance BP guidelines and GT principles of cooperative interaction. This relationship, while representing a heavy reliance on BP, is different than others before it as the assumptions made by 002 were incorrect regarding BP. Therefore, as neither appropriate BP or GT principles were maintained, no relationship was met between 002 and the eMAR.

Scenario 5: Challenging the CNO's Concept of *Appropriate.*

Patient Identification Verification

As in Scenario 1, 002 was able to correctly verify the patient's identification by completing the barcode scan in the appropriate location of the eMAR, and the eMAR verifying this by returning 'correct patient'. Therefore, 002 was able to balance principles of both BP and efficiency. This resulted in a balanced, cooperative payoff matrix.

Medication Verification

This Scenario challenged 002's knowledge regarding the CNO's concept of *appropriateness* in medication administration. 002 correctly scanned the medication in the accurate location on the eMAR screen. The eMAR then returned a notification of a potential interaction between the medication that 002 was about to administer and a medication already administered. 002 spent some time examining the notification. 002 then verbalized the need to consult with another professional prior to administering the medication. 002 cancelled the prompt, held the medication, and ended their Scenario.

002 did not consult the provided drug guide to examine the medications. This interaction demonstrated a heavy reliance on BP to the detriment of efficiency (Figure 10).

Medication Verification		eMAR	
		Cooperate	Defect
002	Cooperate	BP and efficiency balance	**BP heavy. 002 held the administration of the medication based on requiring additional and unnecessary BP checks.**
	Defect	Efficiency heavy	No relationship

Figure 10

Participant 003

Participant 003 self-described herself as a 21-year-old female who had competed a high school education as the time of data collection. 003 did not profess to have any additional or advanced knowledge of electronic medication administration technology other than courses completed as part of her undergraduate nursing curriculum.

Scenario 1: Challenging the CNO's Concept of *Clear*.

Patient Identification Verification

003 was able to correctly scan the patient armband in the appropriate location, as well as confirm the patient's full name. In doing so, 003 was able to equally balance both BP and GT principles. This interaction demonstrates a cooperative payoff matrix where concepts of BP and efficiency are used in balanced decision-making.

Medication Verification

As with both 001 and 002, 003 was unable to cooperatively balance the payoff between BP and efficiency in the second relationship of Scenario 1. 003 correctly scanned the medication, resulting in the eMAR returning a 'correct medication' indicator, and administered the medication to the patient. However, 003 did not independently verify the order as required by best practice. Had 003 done so, she would have noticed the abbreviated forms of 'orally' and 'twice daily' and recognized the order as being *unclear*. Therefore, this relationship is represented by an unbalanced payoff matrix where 003 employed a heavy reliance on efficiency to the detriment of BP.

Scenario 2: Challenging the CNO's Concept of *Complete.*

Patient Identification Verification

In interaction 1 of Scenario 2, 003 appeared to have trouble following the correct verification sequence for patient identification. 003 attempted to scan the patient identification wrist band but used the wrong location on the eMAR screen to validate the identification. As such, 003 were unable to correctly identify the patient using the electronic record. Further, 003 failed to recognize the lack of eMAR verification and did not compensate with additional manual BP identification checks. Therefore, 003 continued onward in the Scenario only having verified the identity of patient by asking the patient to state their name. This approach by 003 reflects a noncooperative relationship where abilities of the eMAR were not utilized, nor were properties of BP maintained. As such, the payoff matrix reflects no relationship created between 003 and the eMAR (Figure 11).

Patient Identification Verification		eMAR	
		Cooperate	Defect
003	Cooperate	BP and efficiency balance	BP heavy
	Defect	Efficiency heavy	**No relationship was created as 003 did not follow either BP or the efficiencies of the eMAR.**

Figure 11

Medication Verification

003 sequenced this Scenario differently from the other participants. After scanning the medication in the appropriate section of the eMAR, 003 physically held the medication packaging up to the computer screen, reading and comparing the label of the medication to the order details listed on the eMAR screen – then, subsequently scanned the medication appropriately. As such, 003 was able to quickly identify that the dosage (mg) was missing from the order on the eMAR. 003 verbally noted the *incomplete* order and chose to hold medication administration until the order could be clarified. In this relationship, 003 was able to identify the balancing point between efficiency and the BP guidelines that drove their practice. As such, a cooperative relationship was formed, and the correct actions were taken by both parties (Figure 12).

Medication Verification		eMAR	
		Cooperate	Defect
003	Cooperate	**A relationship of BP and efficiency was balanced by the actions of both parties.**	BP heavy
	Defect	Efficiency heavy	No relationship

Figure 12

Scenario 3: Challenging the CNO's Concept of *Appropriate.*

Patient Identification Verification

As in this relationship with 002, 003 did not attempt to use the eMAR to appropriately identify the patient. 003 was informed of the new Scenario and given a new eMAR page for their demonstration. While 003 did verbally verify the patient's identity using a single identifier (i.e., patient's full name), 003 did not verify this information through the eMAR. As BP standards require a minimum of two patient identifiers, this Scenario cooperated with neither principles of BP nor with concepts of efficiency. As such, 003 was unable to form any cooperative relationship for this interaction.

Medication Verification

This Scenario again challenges the CNO's concept of *appropriate* regarding medication administration. At the onset of the Scenario, 003 was provided with a set of vital signs as assessed by a 'colleague'. This piece of paper did not reflect a date or time of collection. 003 examined the vitals in length and noted the blood pressure to be borderline abnormal. 003 was able to correctly identify the medication they were intending to give would directly affect a patient's blood pressure. After successfully scanning the medication packaging on the correct location of the eMAR and receiving a 'correct medication' notification, 003 chose to hold the medication until they were able to perform their own vital signs assessment.

In this interaction, 003 was able to correctly balance concepts of both BP and efficiency resulting in a cooperative relationship where the appropriate actions were taken by both parties involved. This represents a balanced payoff matrix despite 003 not administering the medication.

Scenario 4: Challenging the CNO's Concept of *Complete.*

Patient Identification Verification

Again, 003 appeared to have struggled with the correct sequencing of patient identification verification. As in Scenario 2, 003 again attempted to scan the patient identification wrist band in the wrong section of the eMAR screen. The eMAR was therefore unable to cooperate with 003 to either correctly or incorrectly verify the patient's identity. While 003 did verbally verify the patient's identity, 003 used only one identifier which does not comply with BP guidelines. This interaction therefore reflects a noncooperative interaction where no relationship was able to be created by 003 and the eMAR. Neither properties of BP nor those of GT were utilized. This payoff matrix does not reflect a cooperative relationship.

Medication Verification

As in Scenario 2, 003 scanned the medication packaging in the correct location on the eMAR. As soon as the eMAR returned a 'correct medication', 003 closely compared the physical packaging of the medication against the order listed on the eMAR. 003 noted that the order on the eMAR was missing a route of administration. 003 therefore chose to hold the medication and call the provider to clarify the order. This interaction reflects a cooperative relationship. As in previous Scenarios, even though 003 did not administer the medication, 003 were able to appropriately strike a payoff balance between BP and GT principles.

Scenario 5: Challenging the CNO's Concept of *Appropriate.*

Patient Identification Verification

Unlike the previous two Scenarios, 003 was able to correctly scan and identify the patient with the assistance of the eMAR. 003 scanned the patient's identification wrist band in the correct location of the eMAR screen prompting a 'correct patient' notification. In combination with 003's verbal identification check of the patient, 003 was able to satisfy both elements of BP and efficiency.

Medication Verification

In this Scenario, 003 was challenged to consider the *appropriateness* of the medication to be administered. 003 was able to correctly scan the medication in the appropriate location on the eMAR. This triggered the eMAR to notify 003 regarding the potential for medication interaction with another medication. 003 closely examined the notification prior to cancelling the message. 003 then proceeded to consult the medication drug guide and compare it to the medications on the eMAR. 003 was unable to identify the medication interaction despite using the guide. 003 then verbalized the need to utilize other resources including to "Google it" and consult another medical professional.

In this interaction, 003 and the eMAR collaboratively identified that the medication was both *clear* and *complete.* However, despite being given a resource (i.e., medication drug guide) to assist in correctly identifying the medication as also being *appropriate,* 003 was unable to confirm this. As such, 003 chose to hold the medication. This reflects a heavy reliance on BP to the detriment of the efficiency. While 003 and the eMAR initially appeared to cooperate, 003 was unable to acquire balance between BP and principles of GT (Figure 13).

Medication Verification	eMAR	
	Cooperate	Defect

003	Cooperate	BP and efficiency balanced	**BP heavy. Despite having the resources to proceed with administration, 003 chose to complete unnecessary checks resulting in decreases in efficiency and GT principles.**
	Defect	Efficiency heavy	No relationship

Figure 13

Participant 004

004 was a self-identified 21-year-old female student, who had just recently completed all necessary requirements to obtain her undergraduate degree in nursing. 004 denied any advanced knowledge of electronic medication administration beyond the material covered during her nursing simulation courses.

Scenario 1: Challenging the CNO's Concept of *Clear.*

Patient Identification Verification

004 began Scenario 1 by scanning the patient's identification arm band in the incorrect location of the eMAR screen. As such, the eMAR was unable to confirm that it was the correct patient. This error was missed by 004 who went on to verbally confirm the patient's full name as per BP guidelines. However, because the eMAR was unable to confirm the identity of the patient and 004 did not verify with additional checks as required by BP, no cooperative relationship was formed between 004 and the eMAR (Figure 14).

Patient Identification Verification		eMAR	
		Cooperate	Defect
004	Cooperate	BP and efficiency balance	BP heavy
	Defect	Efficiency heavy	**No relationship was created as 004 did not follow either BP or the efficiencies of the eMAR.**

Figure 14

Medication Verification

As with the previous cases, 004 was unable to balance the payoff matrix for this interaction. 004 correctly scanned the medication packaging in the appropriate location within the eMAR. The eMAR confirmed the medication by returning the "Correct medication" indicator. 004 appeared to read the order on the eMAR screen but did not verbalize this. 004 then proceeded to administer the medication to the patient. This interaction is an example of an efficiency heavy relationship established between 004 and the eMAR where elements of BP were sacrificed to the efficiencies created by the eMAR.

Scenario 2: Challenging the CNO's Concept of *Complete.*

Patient Identification Verification

Unlike in the previous Scenario, 004 was able to correctly scan the patient identification band in the correct location of the eMAR screen. As such, the eMAR was able to positively identify the patient's medication record as correct. 004 verbally verified the patient's identity independently in order to satisfy BP standards. As a result of the actions of the eMAR and 004, a cooperative relationship was achieved.

Medication Verification

004 began this interaction by correctly scanning the medication within the correct location on the eMAR screen. The eMAR was then able to verify that the medication in question was the medication indicated on the eMAR. After this verification, 004 compared the medication to the written order on the eMAR screen. 004 then successfully noted that the dosage was missing from the eMAR order. 004 verbalized that they needed to call the ordering physician to clarify the order. This relationship demonstrates cooperative interaction between 004 and the eMAR despite the medication being held. Not only is this a cooperative relationship but it is also balanced as principles of both GT's efficiency and BP were achieved (Figure 15).

Medication Verification		eMAR	
		Cooperate	Defect
004	Cooperate	**A relationship of BP and efficiency was**	BP heavy

		balanced by the actions of both parties.	
	Defect	Efficiency heavy	No relationship

Figure 15

Scenario 3: Challenging the CNO's Concept of *Appropriate.*

Patient Identification Verification

004 was able to correctly scan the patient's identification wrist band within the appropriate location of the eMAR screen. This subsequently allowed the eMAR to return the "Correct Patient" indicator. 004 then verbalized the independent verification of the patient's identity, thus satisfying the both requirements for BP and efficiency. As such, this interaction reflects a balanced cooperative relationship between 004 and the eMAR.

Medication Verification

This Scenario challenged 004 to identify if the medication to be administered to the patient was *appropriate* or not. At the beginning of the Scenario a set of vital signs was presented to 004 collected by a colleague. There was no indication of the time or date of collection. 004 addressed the reported vitals after verifying the patient's identity. 004 noted that the blood pressure was "on the low side". However, instead taking the corrective actions that would align with BP (i.e., repeating the vitals prior to administration), 004 stated: "Drink some fluid, you'll be ok".

After this determination, 004 correctly scanned the medication packing barcode within the appropriate location of the eMAR screen. The eMAR was then able to provide the indication that the scanned medication matched the medication on the eMAR. 004 verbalized the '8 medication rights' as well. This relationship demonstrates a heavy reliance on efficiency to the detriment of BP guidelines on safe medication administration. Therefore, the payoff matrix for this interaction was unbalanced.

Scenario 4: Challenging the CNO's Concept of *Complete.*

Patient Identification Verification

As in previous examples of the Patient Identification Verification phase, 004 was able to correctly scan the patient's armband within the correct location of the eMAR screen and verbally confirmed the patient's name. In doing so, 004 and the eMAR were able to create a cooperative relationship represented by a balanced payoff matrix.

Medication Verification

004 was challenged to identify that the route of administration for the scheduled medication that was missing from the electronic order. 004 appropriately scanned the medication within the correct location on the eMAR screen. While the eMAR reported "Correct Medication" to the patient, 004 noted the lack of a disclosed route for administration. 004 stated that they would call the ordering physician to clarify the order prior to administering the medication.

In this phase of the Scenario, 004 was able to appropriately identify the *incomplete* element of the medication. The medication was correctly held by 004 until it could be modified by the ordering physician. In this interaction, the eMAR was able to correctly identify the medication as the scheduled medication on the eMAR. Based on the actions by both 004 and the eMAR, a balanced, cooperative GT relationship was formed.

Scenario 5: Challenging the CNO's Concept of *Appropriate.*

Patient Identification Verification

004 again showed competence in correctly scanning the patient's armband and verbally verifying the patient's identification. As these actions allowed the eMAR to complete its verification functional, the principles of BP were met, allowing 004 and the eMAR to successfully create a cooperative relationship that balanced both concepts of BP and efficiency.

Medication Verification

During this phase of Scenario 5, 004 demonstrated some contradictory actions regarding the administration of the medication. 004 correctly scanned the medication label in the appropriate location on the eMAR screen. This prompted the eMAR to advise 004 on the potential for an interaction with another medication. 004 firstly verbalized that the order was "complete" before addressing the eMAR's notification. After this, 004 advanced the Scenario by clicking the ‘continue’ button on the notification window. This prompted the eMAR to then return a “correct medication” response.

At this point in the interaction 004 paused to examine the other medication outlined as ‘given’ on the eMAR. 004 spent a few minutes examining this information before stating that the two medications were not contraindicated with each other. Despite this proclamation, 004 then stated that she needed to “look into it” and decided to hold the medication. 004 did not attempt to use the available medication guide resource nor inquire if they had the ability to use other internet-based resources to review details about the medication in question. As a result, 004 inappropriately held the medication. This relationship is demonstrated by an unbalanced GT payoff matrix where 004 demonstrated a heavy reliance on BP principles sacrificing the efficiencies that the eMAR has to offer (Figure 16).

Medication Verification		eMAR	
		Cooperate	Defect
004	Cooperate	BP and efficiency balanced	**BP heavy. 004 had the resources available to confidently proceed with administration without additional consultation.**
	Defect	Efficiency heavy	No relationship

Figure 16

Finding and Analysis Summary

In this section, each participant’s actions and decisions will be summarized, drawing from insights described in the previous *Findings and Analysis* section (i.e., outcomes of the five Medication Administration Scenarios). Further, this section will also be informed by meaningful quotes drawn from participant’s individual semi-structured interviews that can assist in better summarizing the decision-making or actions made by each participant during the Medication Administration Scenarios.

Participant 001

Overall, with a total of ten interaction points between 001 and the eMAR, a cooperative, balanced payoff was achieved five times during the ten points of interaction during the

Scenarios. The five occurrences of balanced payoff matrices were all generated during the initial interaction between participant 001 and the eMAR at the beginning of each Scenario, which necessitated 001 to conduct appropriate Patient Identification Verification. The Patient Identification Verification phase of medication administration involved a dichotomous decision by the participant to either *agree* or *disagree* with a visual prompt generated by the eMAR (i.e., green prompt on the eMAR record to denote congruency between the scanned patient identification wrist band and the identity linked to the eMAR; red prompt on the eMAR record to denote any inconsistency between the scanned patient identification wrist band and the identity linked to the eMAR). Participant 001 appeared to have no difficulty managing this phase (Patient Identification Verification) of the medication administration process.

However, during the Medication Verification phase, participant 001's actions were noticeably different than those captured during the Patient Identification Verification phase. The Medication Verification phase of the medication administration procedure was arguably more reliant on a participant's understanding of the correct process, ordering, and workflow to correctly scan a patient's barcoded armband, prior to interpreting the green or red prompt generated by the eMAR. During the interview portion of this study, participant 001 indicated that they were initially "confused" by the eMAR system, describing that "it's been a while, so it was a little confusing. At first, I'm so used to like, the [hospital name] PowerChart so I was expecting a little more clicks and scans and stuff like that". However, given participant 001's ability to adequately and efficiently balance the payoff relationship during the Patient Identification Verification phase, 001's performance and verbalized 'confusion' during the Medication Verification phase was a surprising reaction. During the Medication Verification phase, nearly all of participant 001's interaction relationships became efficiency heavy. As a result of this, BP standards were repeatedly compromised by participant 001 throughout the entirety of the Medication Verification phase. For instance, in three of the four examples where efficiency drew prominence, the orders were identified as either unclear or incomplete, while the fourth examples were inappropriate. Despite unknowingly compromising various BP standards in the Medication Administration phase, participant 001 verbalized during interview several references to their use of clinical judgment and the "8 checks [rights]" in determining if a medication was to be administered or not. This is of particular interest as three of four examples of participant 001's efficiency heavy interactions with the eMAR appear to have been potentially simulated by preexisting knowledge of the outdated medication *rights* approach (i.e., right medication, right time, right dose, etc.), instead of the *clear, complete,* and *appropriate* approach currently enforced by the CNO. Further, in addition to the operationalization of an incorrect Medication Verification heuristic, participant 001 also verbalized an overarching desire to be efficient, stating: “I try to be efficient but if I needed more time to think about it of what medication is giving based on the assessments then I took more time”.

In summary, participant 001 was able to achieve a cooperative interaction and balanced payoff during the Patient Verification phases of the Scenarios. However, during the Medication Verification phases of the various Scenarios, participant 001 heavily utilized an out-of-date verification heuristic (i.e., 8 medication rights), which appears to have resulted in generating efficiency heavy outcomes as related to participant 001’s interaction with the eMAR. While participant 001 verbalized “confus[ion]” regarding the use of the eMAR system in the study with another system used in clinical practice, it would appear that the influence of the out-of-date verification heuristic was also a significant factor in their resulting efficiency heavy medication administration, and subsequent repeated compromisation of contemporary BP standards.

Participant 002

002 reported no challenges with the use of the system during the interview. This was of interest as 002 had multiple examples where improper use of scanning techniques resulted in deviation from BP principles. This included Scenario 2 where 002 was unable to scan the patient identification armband in the correct location on the eMAR. Despite not receiving a ‘correct patient’ indicator from the eMAR, 002 even mentioned how they “appreciated the flags” as a “triple check” specifically regarding patient identification. This belief was increasingly contradictory to 002’s actions during the next two Scenarios as she neglected to appropriately identify the patient in any way, electronically or otherwise.

Despite 002’s varied performance, she expressed confidence in medication administration stating they felt “reassurance” and that they did less “second guessing” during this process. Again, these statements ran contrary to her observed performance. During Scenario 4, 002 inappropriately held a medication based on a clinically incorrect assumption regarding the patient’s vital signs. While this Scenario did not intend to challenge 002’s understanding of *appropriate,* 002 made a number of incorrect assumptions that shifted the focus of this Scenario. 002 was initially challenged to note the absence of a route of administration. However, 002 chose to hold administration of the medication not due to the incomplete order but based on the patient's stable vital signs. This was of particular interest as 002's assumptions were not clinically based, indicating a lack of understanding regarding the basic assessment and reason this patient was taking this particular medication. During their interview, when directly asked about the CNO's concept of *appropriate*, 002 stated, "making sure that giving the med makes sense giving it to that patient for their specific situation". This statement indicates that 002 felt she had a deep understanding of her patient and their needs in the context of why the medication in question was prescribed and to be given at this time. However, 002 was unable to demonstrate this understanding during Scenario 4.

002's overall performance and responses to the interview questions indicated that while they had awareness of BP principles of *clear, complete*, and *appropriate,* they did not demonstrate understanding or insight toward how to actualize these principles effectively in practice. Given 002's difficulties interacting with the eMAR itself, and their difficulties fully comprehending the principles of BP, 002 was unable to reliably or consistently create balance between BP and efficiency.

Participant 003

Consistently 003 was able to achieve a cooperative balance between BP principles and efficiency five times during the course of the demonstration. The remaining interactions were a mix of the other three outcomes: three instances of not forming a relationship, and one each of efficiency heavy interaction and BP heavy interaction. During interview, 003 expressed insight into her own medication administration practices and assumptions. 003 discussed her reliance on the eMAR to "do everything for you", stating that "I didn't realize it was so much of a false perception" regarding the trust that she had placed upon the technology to be correct. 003 discussed her own assumptions regarding this trust and how she was "too comfortable with technology" at times relying on the assistive decision support resulting in the potential of elements that "easily could have been missed".

Despite this understanding of safe medication administration concepts, 003 admittedly struggled with elements during the Scenarios. 003 noted that the CNO's medication administration standards had not been fully "challenged" or embedded within eMAR simulation classes she had taken. She also felt that simulation class was completed in an environment where system errors were not present and therefore did not force her to inspect whether an order was indeed *clear, complete,* and *appropriate.* These challenges were further expressed in some of 003's interaction with the eMAR during the demonstration. During Scenario 5, 003 went to increasing lengths to verify the *appropriateness* of administration following the notification of potential drug interactions. 003 stated that they struggled with the drug guide, commenting that she was unclear how to use the medication guide (i.e., "…I don't know how to use this book…") and further stating: "I guess I rely a lot on being able to click on a drug [to learn further details of the medication]." It would appear that 003 placed significant reliance on the eMAR system to not only be correct, but also to supply the user with the resources necessary to assist in situations of uncertainty.

Regardless, 003 was largely able to demonstrate cooperative relationships throughout the Scenarios during both the Patient Identification Verification and Medication Verification phases. Further, 003 also expressed insight into potential issues surrounding overdependence on the eMAR.

Participant 004

Of all the participants, 004 was able to achieve the most interactions with the eMAR that represented a balanced, cooperative payoff relationship. 004 was able to achieve these six times in both the Patient Identification phases and the Medication Verification phases. 004 demonstrated two instances of heavy reliance on the eMAR and its efficiencies, both during the Medication Verification phases.

004's initial interaction with the eMAR demonstrated some difficulty regarding the general use of the barcode scanning process. This was the single interaction where 004 was unable to form any relationship with the eMAR. Despite this, 004 commented on the ease of use of the eMAR system during their interview. During the interview phase, 004 spent a great deal of time discussing her confidence in medication administration. 004 stated, "I feel like I was methodical. They teach you a certain order of how to do your checks in nursing school, so it's pretty efficient to do that". 004 described this "order" as the CNO's eight *rights* of medication administration, stating: "they give us the eight rights of medication administration to apply so during my practice, I… focus on making sure each of those are checked off. So I have them memorized and then I just apply them". When questioned regarding the CNO's newer principles-based approach of *Clear, Complete,* and *Appropriate*, 004 likened the eight rights to *Complete*. 004 further equated *Appropriate* to the "patient's clinical status". Further to these comments, 004 expressed a belief that it takes, "more practice [to] step away from the eight rights to *Clear, Complete,* and *Appropriate*" and that for "…learning purposes definitely I stuck with the eight rights for medication administration…" and that "…abstract concepts come with time". Overall, while 004 was successful in creating balanced, cooperative relationships with the eMAR, she also continued to rely heavily on an outdated medication *rights* heuristic.

Discussion

Several common themes emerged from the findings of this study related to how optimization processes influenced nursing students perform electronic medication management activities.

The Generation of a *No Relationship* Situation

Based on GT, it was assumed nursing students would divert their decision-making tendencies to aspects of BP, efficiency, or strike a balanced payoff between these two potential outcomes. However, early in the interpretation of findings, it was discovered that the fourth option of *no relationship* between either BP principles or process efficiency was a common outcome for many of the Medication Administration Scenarios. With exception of participant 001, all other participants demonstrated at least one instance of this *no relationship* outcome. This is particularly concerning as this outcome does not rely upon the principles of BP in medication administration nor on the safety features programmed into the eMAR. As such, this demonstrates that the basic principles of safe medication management were not being adhered to, electronically or otherwise. This troubling outcome may indicate a far more rudimentary issue with eMAR administration education.

In the majority of instances where a *no relationship* outcome occurred, the participant generated this outcome during their first few interactions with the eMAR system. It can be speculated that this occurred primarily due to unfamiliarity with the eMAR system used in this study (Lin et al., 2017). While all participants had previously used the same system in their undergraduate education, some of the participants mentioned that it had been some time since they last used the system. Despite this observed initial difficulty interacting with the eMAR system, nearly all of the participants described the eMAR system as *easy to use* in some fashion during their interviews or that they were comfortable using it. However, instances of *no relationship* outcomes being generated were found throughout other elements of the Medication Administration Scenarios. While fewer in number, the presence of these *no relationship* outcomes in later elements of the Medication Administration Scenarios suggests that familiarity with the eMAR system was likely not the sole cause of *no relationship* encounters.

Use of a *Medication Rights* Approach to Medication Administration

According to the Medication Administration Practice Standard, RNs are required to ensure a medication order is: “clear, complete, and appropriate” (College of Nurses of Ontario, 2017, p. 3). Prior to the development of the principles-based *clear, complete*, and *appropriate* requirements of medication administration, a heuristic of five to eight *rights* (i.e., right medication, right dose, right time, etc.) was commonly used to guide best practice in medication administration (Anest, 2013; Booth et al., 2017c; Krautscheid et al., 2011; Novak et al., 2013). However, based on the numerous instances of participants in this study leveraging some aspect the medication *rights* to inform their decision-making, it would appear that principles-based approaches were not fully understood by study participants. For instance, the persistent nature of the use of the medication *rights* by all participants could be potentially explained by the comments Participant 004 made during their interview when questioned how she used *Clear, Complete,* and *Appropriate* in her practice. Upon reflection, Participant 004 described how the abstract nature of *Clear, Complete,* and *Appropriate* is only fully understood with time and experience. Whereas the *rights* provide a checklist of easily definable elements for student and novice nurses to “check off”. Unfortunately, in its current form, the medication *rights* heuristic does not address one of the central elements of medication management: the *appropriateness* of the medication related to the patient’s current health situation and context. This suggests that a medication order may satisfy the medication *rights* heuristic, yet be inappropriate for administration (Cohen & Smetzer, 2017).

Inherent Trust in eMAR Technology

As suggested by previous researchers, there appears to be an inherent trust in eMAR systems to identify mistakes in medication orders, and to assist in verifying both patient identity and the medication to be administered (Cohen & Smetzer, 2017; Hawkins et al., 2017; Jenkins, Eide, Smart, & Wintersteen-Arleth, 2018). Evidence of this inherent trust in the eMAR system was expressed in the outcomes of several Scenarios by all participants in this study. While all participants had interactions where created relationships had a heavy reliance on the eMAR and its efficiencies, only one participant discussed their assumptions pertaining to the veracity of the eMAR system itself. Participant 003 expressed how they could easily become "too comfortable with technology" and how this comfort and reliance on electronic systems may be a detriment to critical thinking. While eMAR systems have been found to be relatively reliable (Hoonakker et al., 2013; Kaushal et al., 2003; McBride, Delaney, & Tietze, 2012), other research has explored how these forms of health technology have the potential to generate unintended consequences (Koppel et al., 2005; Kutney-Lee & Kelly, 2011; Poon et al., 2010), including overreliance or trust on the decision-support functionalities afforded by the system. Further research should be completed to explore the concept of trust in relation to eMAR, and how it is conceptualized by nurses who use these sorts of systems for medication administration.

Limitations

There are several limitations that ought to be discussed and considered when interpreting the findings and implications of this study. First, due to the unexpected difficulty in recruitment, the study size was smaller than desired. A larger sample size would have potentially allowed for deeper saturation of various findings and themes uncovered in the study. Second, the qualitative nature of this study limits generalizability of the findings. Although caution has been taken in the reporting of findings in this study to avoid extrapolation to larger cohorts of the nursing student population, caution is suggested when interpreting the findings of this study beyond the local context from which the data was collected. Finally, while all participants had previously used the eMAR system during their undergraduate nursing education, the amount of time between participants' exposure to the SMART eMAR and data collection in this study varied. This variation may have resulted in participants generating errors early in the demonstration as students refamiliarized themselves to the system.

Conclusion

To date, the decision-making processes that guide nursing students' administration of medications using eMAR systems has not been widely explored. Overall, students appeared to exhibit heavy reliance on the eMAR system, creating an unbalanced relationship with the technology. This reliance came at the cost of BP principles of safe medication management practices. Further, the occurrence of *no relationship* interactions was also uncovered as a significant finding of this study – insomuch as students demonstrated neither BP or administration efficiency during elements of the scenarios. Finally, participants consistently used elements arising from the medication *rights* heuristic to guide aspects of the administration. It was speculated that the abstract nature of principles-based *Clear*, *Complete*, and *Appropriate* approach currently advocated by the CNO (2017) for medication administration may not have been fully understood by student participants.

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CHAPTER THREE

The aim of this qualitative descriptive study was to explore how student nurses optimize their medication management practices using eMAR technology in their simulated practice. Three primary thematic findings were generated based on the data collected and analyzed, arising from the participants' completion of the scenario demonstration and the interview portions of this study: (a) The generation of a *No Relationship* situation; (b) Use of a *Medication Rights* approach to medication administration; and, (c) the inherent trust in eMAR technology. While there were examples of interactions that exhibited balanced relationships between principles of Best Practice (BP) and administration efficiency, there was little consistency in the relationships generated either within a singular participant's actions, or collectively amongst all study participants. As such, future efforts should be undertaken to better define and examine the relationships between BP and administration efficiency using eMAR, and how educators can better develop teaching-learning strategies that balance the importance of both dimensions within the administration process.

Implications for Nursing Education

Medication administration practices are one of the central roles of Registered Nurses which differentiate them from other clinicians and support worker roles (College of Nurses of Ontario, 2017; Spaulding & Raghu, 2013). As such, well developed curricula are required to ensure appropriate principles and methods are leveraged during nursing education to support students using eMAR. For instance, the use of simulation within baccalaureate nursing education has been used to provide students with safe learning environments to practice their skills (Cant & Cooper, 2017; Lawrence, Messias, & Cason, 2018; Lestander, Lehto, & Engström, 2016). As electronic administration approaches become more prevalent in simulation environments, care must be taken to ensure teaching-learning methods completely move away from *medication rights* approaches and focus on a principles-based approach to administration management (i.e., *Clear, Complete*, and *Appropriate*). Further, the findings of this study suggest it is also important for educators to explore the decision-making processes involved in navigating the relationship between eMAR systems and students. Educators must critically examine and reflect upon their own assumptions and practices regarding eMAR administration and how various aspects like clinical decision-making and workflow are fundamentally changed by the inclusion of an eMAR system into the administration process. Involvement in further research, critical evaluation of current medication administration processes, and development of eMAR-sensitive teaching-learning approaches within nursing education are suggested as immediate next-steps to improve education surrounding eMAR administration.

Implications for Nursing Practice and Research

The wide-scale adoption of clinical technology into practice environments where nurses' work has been a significant driver in the evolution from paper-based to electronic medication administration processes (Chung & Cho, 2017; Herbert & Connors, 2016; Titzer & Swenty, 2014). During the initial changes in eMAR implementation, nursing research has struggled to keep up with these practice changes and generate evidence to support nursing practice. These struggles have led to students and new nurses having inconsistent experiences using eMAR systems, and a general lack of understanding regarding standard electronic medication management best practices (Booth, Sinclair, Brennan, & Strudwick, 2017a; Whitt, Eden, Merrill, & Hughes, 2017).

As a result of this, eMAR administration practices of nurses has only recently begun to receive wider attention within nursing research. While the effectiveness of eMAR systems to successfully reduce medication errors has been widely researched (Koppel et al., 2005; McComas, Riingen, & Chae Kim, 2014; Poon et al., 2010; Staggers, Iribarren, Guo, & Weir, 2015), the types of relationships and decision-making used by nurses is an area that has yet to be fully explored. For example, multiple studies exist associating the use of eMARs decision-making capabilities to decreases in medication error rates (Franklin, O'Grady, Donyai, Jacklin, & Barber, 2007; Kruse, Beane, Hall, & Marcos, 2018; Poon et al., 2010). Further, other studies have also examined risks linked to unintended consequences of eMAR technologies including workarounds, impacts on perceived quality of care, and over-reliance on technology (Cohen & Smetzer, 2017; Gellert et al., 2017; Gooder, 2011; Zhou, Ackerman, & Zheng, 2011). Fewer studies exist exploring the relationships between social and technical factors that are active when systems like eMAR are used by nurses -- including how the relationships between the nurse and eMAR influence aspects like clinical decision-making or process workflow (Booth et al., 2017a; Booth et al., 2017b; Jenkins et al., 2018). Based on the findings of this study, the exploration of these social and technical factors present during medication administration using eMAR may hold deeper insights into the development of successful educational practices to facilitate patient safety and other process efficiency requirements. As health technology continues to infuse into all aspects of nursing practice (Kruse et al., 2018; Maalouf, Sidaoui, Elhajj, & Asmar, 2018; Manashty & Light, 2019), generating deeper understanding of the fluid, dynamic relationship between nurses and technologies used for practice will be paramount.

Summary

The findings highlighted in this study demonstrate that students use a variety of decision-making approaches when completing eMAR administration. The balance of BP principles and administration efficiencies are an area in need of further exploration, especially given the inconsistent findings generated in this study in terms of balancing BP with efficiency. It is advocated that generating deeper understanding related to the decision-making of students using eMAR is required, in order to generate better teaching-learning strategies for safe electronic medication administration in nursing education.

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APPENDICES

Appendix A: Ethics Certificate

Western Research

Date: 10 December 2018

To: Dr. Richard Booth

Project ID: 112870

Study Title: Optimization of Electronic Medication Administration in Safe Medication Management During Nursing Education

Application Type: HSREB Initial Application

Review Type: Delegated

Meeting Date / Full Board Reporting Date: 18/Dec/2018

Date Approval Issued: 10/Dec/2018

REB Approval Expiry Date: 10/Dec/2019

Dear Dr. Richard Booth

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

Document Name	Document Type	Document Date	Document Version
Appendix A- Research Presentation	Flow Diagram	20/Nov/2018	V2
Appendix B- Letter of Information and Consent	Written Consent/Assent	20/Nov/2018	V2
Appendix D- Demographic Info	Paper Survey	20/Nov/2018	V2
Appendix E- Interview Guide	Interview Guide	20/Nov/2018	V2
Appendix G- Collection Tool	Participant Observation Guide	20/Nov/2018	V2

Documents Acknowledged:

Document Name	Document Type	Document Date	Document Version
Appendix F- Workflow Diagram	Flow Diagram	20/Nov/2018	V2
Appendix H - SMART eMAR Example	Flow Diagram	20/Nov/2018	V2
Appendix O- References	References	22/Oct/2018	1

No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB , except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Patricia Sargeant, Ethics Officer (ext. 85990) on behalf of Dr. Philip Jones, HSREB Vice-Chair

Appendix B: Semi-Structured Interview Guide

Semi Structured Interview Guide

1. How did you feel using the SMART electronic medication administration record?
2. How did you feel responding to the different scenarios?
3. How do you feel you used your time?
4. What do you feel is best practice in electronic medication administration?
    a. How did the College of Nurses of Ontario's (CNO) standard on medication administration influence your practice?
5. Do you feel confident in electronic medication administration? Why/why not?
6. What were the challenges, if any, you experienced while demonstrating electronic medication administration?
    a. Did you feel prepared?
    b. What emotions were you feeling during administration?

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10.1097/NNE.0000000000000361

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