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I, Tara Konicki, hereby submit this original work as part of the requirements for the degree of Doctor of Philosophy in Nursing - Doctoral Program.

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The Effect of Simulation on Hand Hygiene Knowledge, Beliefs, and Behaviors of Nursing Students

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The Effect of Simulation on Hand Hygiene Knowledge, Beliefs, and Behaviors of Nursing Students

A dissertation submitted to the Graduate School of the University of Cincinnati in partial fulfillment of the requirements for the degree of

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by

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Abstract

Although hand hygiene remains an essential aspect of quality care, adherence to best patient safety practices continues to pose major challenges. Using an experimental pretest-posttest design, this study examined hand hygiene knowledge, beliefs, and behaviors in a convenience sample of sophomore nursing students. The control and intervention groups received the same 45 minute lecture pertaining to hand hygiene and 3 data collection points where van de Mortel’s Hand Hygiene Questionnaire (HHQ) was administered. In addition, the intervention group viewed a 6.5 minute video “Partnering to Heal” (U.S. Dept. of HHS) and participated in 4 simulated situations requiring hand hygiene, based on World Health Organization guidelines. For all students, the hand hygiene technique was assessed through the use of Glo Germ, followed by handwashing and photography under ultraviolet light (posttest only). Image illumination was analyzed using ImageJ (NIH). Microbiological sampling plates (pretest-posttest) were assessed quantitatively by colony counting. Study findings did not support differences in the intervention group for the 5 hypothesized relationships. During the study, several threats occurred affecting the reliability of the instruments and validity of the subsequent measurements. For instance, social desirability responding and negative item confusion were found to occur with the HHQ in the student population. Interestingly, there was a significant difference in the UV hand photographs, with students in the afternoon having lower values than students in the morning. Given the study results, there were no definitive educational recommendations to teach hand hygiene to nursing students. Future research should continue to further examine multi-focal modalities to enhance adherence to hand hygiene practices, as well as control for extraneous mediating or moderating variables found in educational settings. Additional research is needed to develop a questionnaire reliable in a beginning nursing student population.
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Table of Contents

**Chapter 1: Introduction** .................................................................................. 1

Background ........................................................................................................ 1-3

Purpose of the Study .......................................................................................... 3

Theoretical Framework ....................................................................................... 4-7

Research Hypotheses ......................................................................................... 7-8

Importance of the Study .................................................................................... 8

Scope of the Study ............................................................................................. 8

Definition of Terms .......................................................................................... 9

Summary ............................................................................................................ 9

**Chapter 2: Literature Review** ....................................................................... 10

Healthcare-associated Infection ........................................................................ 10-13

Hand Hygiene Effectiveness ............................................................................. 13-15

Behavioral Issues with Hand Hygiene Compliance ....................................... 15-19

Nursing Students and Hand Hygiene ............................................................... 19-21

Nursing and Simulation .................................................................................... 21-23

Conclusion ........................................................................................................ 24

**Chapter 3: Research Methods** .................................................................... 25

Research Design ................................................................................................ 25

Participants ........................................................................................................ 25-26

Human Subjects Protection .............................................................................. 26-27

Instrumentation ................................................................................................ 27-29

Study Research Procedures and Data Collection Process ............................. 29
Phase I ...........................................................30
Phase II ...........................................................30-32
Phase III ...........................................................32-33
Phase IV ...........................................................33-34
Data Analysis .......................................................34-46
Assumptions of the Study ........................................36
Limitations of the Study ...........................................37
Summary ...........................................................37

Chapter 4: Results .................................................38

Introduction .......................................................38
Sample .............................................................38
Methods ...........................................................38-43
Analyses ...........................................................43-44
Construct Validity ...............................................44
Reliability ...........................................................44-45
Descriptive Statistics - Univariate ............................45-50
Bivariate ...........................................................50-51
Principal Components Analysis ...............................51-56
Inferential Statistics .............................................56
HHQ Analysis ....................................................56-58
Microbiological Count Analysis ..............................58-59
Integrated Density Analysis ..................................59
Threats to Validity and Reliability ............................60-65
Conclusion.............................................................................................................66

Chapter 5: Summary ..............................................................................................67

Introduction ........................................................................................................... 67

Methodology .......................................................................................................... 67-69

Suggestions for Future Research ...........................................................................69-73

Conclusion ..............................................................................................................73-74

References .............................................................................................................75-85

Appendix 1 Abbreviations .....................................................................................86-87

Appendix 2 Histograms HHQ ................................................................................88-92

Appendix 3 Reduction in Microbe Growth by Group ...........................................93-97

Appendix 4 Microbiological Precount by Group ..................................................98-99

Appendix 5 Microbiological Postcount by Group ...............................................100-101

Appendix 6 Histograms Integrated Density by Group .........................................102-103

Appendix 7 Scatterplots .........................................................................................104

Appendix 8 Integrated Density and Microbiological Postcount ...........................105
List of Tables

Table 1 Study Research Procedures.................................................................29
Table 2 Scenarios............................................................................................31
Table 3 HHQ Scale Descriptives.................................................................45
Table 4 Microbiological Counts and Integrated Density.............................49
Table 5 Microbiological Counts by Clinical Group........................................49
Table 6 Initial Eigenvalues First Iteration.....................................................52
Table 7 Communalities First Iteration............................................................52
Table 8 Eigenvalues Second Iteration............................................................53
Table 9 Communalities Second Iteration.......................................................53
Table 10 Component Loadings Third Iteration..............................................54
Table 11 Communalities Fourth Iteration......................................................54
Table 12 Eigenvalues Fifth Iteration.............................................................55
Table 13 Communalities Fifth Iteration........................................................55
Table 14 Component Loadings Fifth Iteration.................................................55
Chapter 1

The first chapter of this dissertation will introduce hand hygiene as a problem in healthcare. The quality of hand hygiene studies will be discussed. Behavioral considerations affecting hand hygiene in healthcare workers will be examined. The purpose, importance, and scope of the study will be discussed along with the theoretical framework. Additionally, the research hypotheses will be stated. Important study terms will be defined.

In 1847, Semmelweis was the first to link hand hygiene with infections acquired during hospital care (1861). Hand hygiene is championed as key to decreasing the number of healthcare-associated infections (HAIs). However, the number of HAIs reached 1.7 million with 99,000 resulting deaths in the United States in 2002 (Klevens et al., 2007). Healthcare-associated infections are responsible for approximately $35.7 billion to $45 billion in direct costs to the U.S. healthcare system (Scott, 2009). HAI prevention effectiveness levels of 20 percent to 70 percent have an estimated cost savings range of $5.7 billion to $31.5 billion (Scott, 2009). Despite hand hygiene being linked to significant morbidity, mortality, and cost, it is established in the literature that compliance is difficult to achieve and maintain in healthcare settings. Hand hygiene is a critical patient-safety behavior.

High levels of hand hygiene compliance can decrease HAIs (World Health Organization, 2009). Hand hygiene compliance among healthcare workers in hospitals varies widely. Compliance rates in hospitals average 40% (Erasmus et al., 2010), and one hospital reported a rate of 6.5% in a surgical intensive care unit after video cameras were placed in the unit (Rosenberg, 2011). Research efforts by behavioral scientists have been stymied by the lack of successful behavioral interventions in this educated population.
Overall, hand hygiene compliance studies have lacked rigor (Erasmus et al., 2010). Most studies examined by Erasmus et al. (2010) did not include reliability testing of instruments. In addition, theoretical methods to date have not been effective in altering hand hygiene behaviors. Erasmus et al. examined 96 studies, and only 7 used a theoretical framework to explore behavioral considerations of hand hygiene. Admittedly, hand hygiene is a complex behavior, because it can be affected by healthcare worker factors, as well as workload and workplace resources.

Healthcare workers are expected to know how to prevent healthcare acquired infections (Farley, 2012), and hand hygiene is a major focus of reducing such infections (WHO, 2009). Studies have found varying reasons for noncompliance: intensity of work activity and perception of value placed by administrators (Pessoa-Silva et al., 2011), lesser self-efficacy (De Wandel, Maes, Labeau, Vereecken, & Blot, 2010), and beliefs regarding hand hygiene and transmission of HAIs (Erasmus et al., 2009). The hand hygiene compliance rate of physicians has been found to be lower than nurses, and healthcare workers are more likely to wash their hands after a procedure than before it (Erasmus et al., 2010). A review of educational interventions found that most studies taught hand hygiene technique, but the outcome measures were proper technique and compliance (Cherry, Brown, Bethell, Neal, & Shaw, 2012). Therefore, the problem is that hand hygiene intervention studies have not increased or sustained adherence to hand hygiene guidelines; in addition, educational intervention studies lack a focus on compliance education to healthcare providers.

Research with nursing students, for instance, has shown that beliefs about hand hygiene efficacy and actions by healthcare workers in the hospital influence compliance with hand hygiene guidelines (Erasmus et al., 2009). Students are prone to overestimating compliance to
hand hygiene, as well as their knowledge and abilities (Cole, 2009). This situation is due to the theory-practice gap in nursing; the skills that students learn in school require more knowledge to be used in a work setting (Duchscher, 2009). Students who develop reflective skills and understand the theory behind nursing actions can have an increased appreciation for the connection between theory and practice (Hatlevik, 2012). Simulation is an educational strategy for nursing that allows students to develop confidence and apply classroom theory, as well as build psychomotor proficiency (Hope, Garside, & Prescott, 2011). In addition, simulation allows for role-modeling, repetition, and reflection; these strategies have been shown to influence behaviors.

Educational interventions are effective for increasing hand hygiene compliance in short-term studies (Mathai et al., 2010). Most studies do not report sustainability past one year. A review of educational strategies for hand hygiene found that role-modeling is an integral component of a program. Role-modeling is part of simulation and Social Cognitive Theory (SCT) states that role-modeling is part of observational learning. SCT provides a framework to intervene on the development of personal standards (Bandura, 1991). Nursing students who receive education and an intervention that increases confidence and proficiency are likely to have more self-efficacy, which has a considerable role in promoting action (Bandura, 1991).

The purpose of this study is to use simulation to instruct undergraduate nursing students to increase their knowledge, self-efficacy, positive beliefs, and the curricular importance of hand hygiene. Nursing students who practice patient safety behaviors will be in a better position to do what is expected in the clinical setting (Gantt & Webb-Corbett, 2010). Individual experience is a factor that has been shown to change behavior (Nicol et al., 2009). Individual experiential learning allows the student to learn by doing, incorporated into the training. Simulation allows
for nursing students to experience their training. Education through assimilation, while the norm in hand hygiene education, has not been shown to be effective in changing long-term behaviors (Erasmus et al., 2010). Simulation is an active learning method which incorporates role-modeling, repetition, and reflection to influence learner behavior in accord with Social Cognitive Theory (SCT). The proposed simulation will incorporate “My five moments for hand hygiene” (Sax et al., 2007), which is a program promoted by the WHO to inform healthcare workers when hand hygiene is indicated in the clinical setting. Moreover, simulation can be a prompt to bridge the theory-practice gap, and should be investigated to increase compliance and sustained adherence in hand hygiene.

**Theoretical Framework**

Hand hygiene is often indicated for the protection of the patient from transmission of infectious agents by healthcare staff. Healthcare workers are more likely to perform hand hygiene if they have carried out a procedure considered unclean, thus protecting themselves. A systematic review found this to be the only persistent factor related to increased compliance (Erasmus et al., 2010). The Theory of Planned Behavior (TPB) model has been used in hand hygiene studies, but has had the most success when used to increase healthy self-behaviors. Hand hygiene to protect one’s self is not the problem; hand hygiene to protect the patient is the issue. The TPB has been utilized more often to predict adherence to hand hygiene than for interventional design. The TPB framework has not produced lasting insight into how to increase hand hygiene compliance (Erasmus et al., 2010).

On the other hand, Social Cognitive Theory (SCT) maintains that learning can occur by observation (Bandura, 1986). SCT will be used because it is congruent with the principles of simulation training, and the concept of self-efficacy has been the subject of simulation research.
Hand hygiene behaviors of students have been positively and negatively influenced by behaviors of other healthcare workers (Snow, White, Alder, & Stanford, 2006; Barrett & Randle, 2008). Role models are important to increase compliance to hand hygiene (WHO, 2009). SCT assumes that learning can take place outside of behavior change (Bandura, 1991); this is apparent in hand hygiene studies, as higher education level has been associated with lower compliance (Erasmus et al., 2010).

SCT assumes that personal, behavioral, and environmental elements influence each other in the regulation of behavior (Bandura, 2001). For this study, the personal elements are the nursing student’s beliefs, the behavioral element is education, while the external environment is the nursing skills course.

Motivation and action, when combined with the perception of one’s own capability, can produce behavioral change. Motivation for the nursing student is to advance in nursing school or to provide safe care, while action is the competent performance of hand hygiene. The behavioral change is compliance with hand hygiene guidelines. SCT (Bandura, 2001) states that in order for a person to change his motivation or action, the person must have intention to perform the behavior. The student must plan to perform hand hygiene when it is indicated. Self-regulation is guided by advance consideration of events, or forethought (Bandura, 1986). Plus, self-regulation is the foundation for control of intentional actions (Bandura, 2001). Forethought comes from the development and reflection of ideas. Forethought causes the student to reflect on the possibility of a HAI. On the other hand, self-reactiveness is when the planning and forward thinking stops, and action begins; it encompasses a deliberate execution of hand hygiene to provide safe care. Self-reflectiveness also involves an evaluation of the three stages of intention, forethought, and self-reaction. It permits the student to evaluate the effectiveness of his or her hand hygiene
behaviors to decrease a HAI. The four stages together are human agency; human agency is the decision to learn and change a behavior (Bandura, 2001).

Self-regulation is a system in which a person monitors, judges, and reacts to his own behavior (Bandura, 1991). Efficacy beliefs are also a part of this system. Self-monitoring influences the goals that people set for their behaviors. Reaction to knowledge gained from monitoring allows evaluation, and some people will increase the behavior to reach a new goal. Performance feedback is necessary so that the person will have a good understanding of his strengths or deficits. Simulation allows for behavior monitoring as there can be several students working on a scenario, and the scenario can also be recorded and played back for the students. The students get feedback at the end of the scenario during the debriefing, which is a time for the students to talk about their thoughts and actions during the scenario. The observation of others and feedback could help students to increase the desired behavior by encouraging them to evaluate their actions and set a new goal. Nursing students who have participated in hand hygiene monitoring reported that the experience increased their own compliance, however this was ascertained by self-report and was not a longitudinal study (Waltman, Schenk, Martin, & Walker, 2011).

Personal standards can come from learning or feedback given by others (Bandura, 1986). The judgment aspect of self-regulation requires that people evaluate their own behavior in a positive or negative manner compared to internal rules to measure a behavior as acceptable. Bandura (1991) stated that having criteria for acceptable behavior makes it easier to manage behavior. Simulation in nursing allows for the development of learning objectives and expected behaviors. Students often get assigned preparation work before a simulation scenario, as well as get related lecture content before the scenario is enacted. Simulation encourages development
and evaluation of personal standards through the preparation work and scenario debriefing. Simulation allows nursing students to practice technical skills and critical thinking in an environment similar to what they would encounter in clinical practice. Practicing the application of knowledge can help students to begin to bridge the theory-practice gap.

Reaction to one’s behavior happens after the evaluation (Bandura, 1991). Self-reaction includes rewarding the behavior or halting the behavior to avoid negative feelings. Simulation is used in undergraduate nursing education to prepare students for clinical. Students will be motivated to increase desired behaviors after simulation evaluation, as the behaviors will be utilized in the clinical setting and graded. Simulation can be used to practice specific skills, infrequent situations, and problem-solving (Jefferies & Battin, 2012). Simulation can occur over a wide range like using a task trainer body part to practice skills, all the way to a life-size manikin that can have vital signs and uses medical gases.

The belief that people have in their ability to complete tasks and attain goals is self-efficacy (Bandura, 1991). Self-efficacy beliefs greatly influence a person’s regulation of his behavior. When people consider themselves to have high self-efficacy, they will set higher goals than if they do not perceive themselves to be capable (Bandura, 1991). Therefore, it is important to educate nursing students in a manner that will increase their self-efficacy. Simulation will allow nursing students to practice performing hand hygiene with a patient manikin and gain proficiency, which may increase their self-efficacy beliefs and goal achievement.

**Research Hypotheses**

1. Nursing students who receive standard training plus simulation will have increased knowledge regarding hand hygiene behaviors than nursing students who receive only the standard training.
2. Nursing students who have increased knowledge pertaining to hand hygiene will have more positive beliefs, as measured by the Hand Hygiene Questionnaire (van de Mortel, 2009).

3. Nursing students who receive standard training plus simulation will have more self-efficacy beliefs regarding hand hygiene behaviors than nursing students who receive standard training.

4. Nursing students who receive standard training plus simulation will rate the curricular importance of hand hygiene higher than students who receive standard training.

5. Nursing students who receive standard training plus simulation will have improved hand hygiene technique compared to nursing students who receive standard training.

**Importance of the Study**

This study will advance nursing science through the examination of whether simulation as an educational strategy can be used to address hand hygiene clinical practice for student nurses who are being introduced to clinical skills. SCT testing will be done within the context of HAIs. Observation and modeling, key components of SCT, are integral to simulation. Simulation will facilitate self-regulation by allowing participants the opportunity to monitor, evaluate, and react to their own behavior. The development of personal standards of hand hygiene will be formed through learning, and reinforced by feedback through debriefing.

**Scope of the Study**

This study is being conducted to determine if the intervention group (standard training plus video and simulation) has greater knowledge, positive beliefs, self-efficacy, belief in importance and performance of hand hygiene behaviors than the control group (standard training).
**Definition of Terms**

The term healthcare-associated infection refers to infections that have been contracted during the course of medical care (Centers for Disease Control and Prevention, 2012). Infections may be from bacteria, viruses, or fungi. Hand hygiene is a term that describes cleaning hands by soap and water or alcohol-based sanitizer (CDC, 2012).

Nursing students in this proposal refers to undergraduate nursing students in a bachelor’s degree program. Simulation refers to the imitation of an action by a healthcare worker using an object or manikin (Society for Simulation in Healthcare, 2012). Positive beliefs are the perceptions a student has toward barriers and rewards in hand hygiene (van de Mortel, 2009). Barriers toward hand hygiene include such things as having proper facilities or hygiene products available, as well as negative feelings when approaching others to ask them to perform hand hygiene. Rewards toward hand hygiene include better patient outcomes, provider feelings of confidence, and performance of a duty.

**Summary**

Healthcare-associated infections are responsible for significant morbidity and mortality within the U.S. healthcare system. Hand hygiene is one acknowledged method to decrease HAIs. There are problems with long-term compliance in hand hygiene intervention studies. Educational interventions in hand hygiene studies have not resulted in sustained changes in compliance. Simulation is an educational strategy that allows students to experience their learning, and has the potential to change behavior through practice, observation, and evaluation of performance.
Chapter 2

Literature Review

Healthcare-associated Infection

The purpose of this chapter is to examine the state of hand hygiene science and provide a summary of the science. The problem of HAI will be described, and the importance of hand hygiene in prevention of HAI's will be asserted. Behavioral issues in hand hygiene compliance will be reviewed; these studies have not commonly examined knowledge, attitude, and behavior. The examination of nursing students and hand hygiene will look at the cognitive, behavioral, and affective domains of learning. The use of simulation in nursing will be examined. In general, the rigor of hand hygiene and compliance studies is not high; there is an abundance of self-report, lack of validated and reliable tools, and insufficient agreement across studies of how to measure compliance.

Glance, Stone, Mukamel, and Dick (2011), for instance, used a retrospective cohort study of 155,891 patient records to examine HAI's in trauma patients (all age groups). Data were drawn from the U.S. Nationwide Inpatient Sample (stratified sample), obtained from the Healthcare Cost and Utilization Project. Risk-adjusted logistic regression models were used to determine that patients with HAIs and septic had 6 times the mortality of patients without an HAI; patients with HAIs and not septic had 1.5-1.9 times the mortality of non-HAI patients (Glance et al., 2011). In addition, the researchers found that HAI patient costs were around 2-2.5 times more, and length of stay (LOS) (median) was around 2 times longer, than non-HAI patients. One key assumption of this study is that the researchers accepted trauma patients with infections having HAIs since these patients did not have an admission diagnosis of infection. In this study, Glance et al. (2011) relied on International Classification of Disease (ICD) codes for this study. Use of
the largest database sample of hospital inpatients, as well as limits on inclusion criteria gave this study high statistical conclusion validity. The database used did not allow the researchers to determine if a previously acquired HAI was present on admission, but using a patient population suffering an acute event should make this likelihood low.

Lee, Imanaka, Sekimoto, Ikai and Otsubo conducted another database review research in Japan similar to the Glance et al. (2011) study. The researchers’ sample consisted of 16,866 patients with ischemic stroke, and identification of HAIs was done through ICD codes and antibiotic usage. Risk-adjusted regression models were used. Lee et al. (2011) found that HAI cost increased treatment costs by $3,067. HAI patients stayed in the hospital 16 days longer than non-HAI patients, and had an increased risk of mortality by 23.2% (adjusted odds ratio) (Lee et al., 2011). Sample size and selection of a population healthy until an acute event strengthened the statistical conclusion validity of the identification of HAIs. Limitations were that the severity of stroke and the type of infection was not accounted for, so could not be adjusted.

Cost estimates of HAIs in the U.S. were developed by Hassan, Tuckman, Patrick, Kountz, and Kohn (2010) using data from 1.5 million patients of all ages in the State of New Jersey, including data from the Annual Survey of Hospitals and the Medicare cost report. Hassan et al. created a system of equations to account for the interdependency of the variables of cost, LOS, and incidence of infection. Their findings were that HAIs increased patient cost by $10,375, and LOS by 3 days. The total increased cost to the U.S. healthcare system due to HAIs was an estimated $16.6 billion (Hassan et al., 2010).

Multiple methods of analysis were used to analyze a random sample of 1,253 adult patients (>5 International Classification of Disease (ICD) codes at discharge), at an urban teaching hospital (Roberts et al., 2010). All methods separately confirmed an increased cost ($9-
21,00), and increased LOS (5.9-9.6 days) (Roberts et al., 2010). Mortality due to HAIs in this sample was found to be 6.1%. Roberts et al. excluded patients with less than 6 ICD codes from analysis, which means that the patients were in a high-risk group. Patients with fewer ICD codes may have different outcomes because of lesser acuity of illness.

Emerson et al. (2012) analyzed 136,513 adult admissions from a retrospective cohort at an urban medical center for hazard of readmission. Hazard models were used to predict a readmission hazard of 1.4 in patients with a positive culture after the first 48 hours of hospitalization. Patients with HAIs had a median of 27 days until readmission, while patients without HAIs had a median of 59 days (Emerson et al., 2012). The hospital did have surveillance programs (culturing on admission) for common pathogens in high-risk patients, but low-risk patients were not cultured. This could have inflated the pool of patients with HAIs. Also, there was no way to determine if patients from either grouping were readmitted to another hospital, which would have altered the hazard model.

In another study, Patel, O’Toole, and Larson (2012) used an electronic health record system to track multi-drug resistant gram-negative bacteria (MDR GNB) in a population of 56,235 hospitalized pediatric patients. Multi-drug resistance was defined as resistant to 3 or more groups of antibiotics; additive drug resistance is when more than 1 GNB accumulates resistance to 3 or more antibiotic groups (at least once over study) in a patient without a previous MDR GNB culture (Patel et al., 2012). There were 46 patients with MDR GNB and 39 who had GNB with additive resistance (Patel et al., 2012). The researchers found five patients with additive resistance GNB developed MDR GNB in a single admission. Bacteria obtain resistance to antibiotics from spontaneous mutations or other resistant bacteria through an exchange of genes (Alcamo, 1997). The surveillance of additive resistance in this population shows that resistance
is changing over time while in the hospital on antibiotics. Healthcare workers need to perform proper hand hygiene to avoid transmitting these organisms between the healthcare environment and patients, because transmission will increase the prevalence of antibiotic-resistant bacteria through the exposure of non-infected patients to MDR GNBs.

Tabah et al. (2012) examined hospital-acquired bloodstream infections (HA-BSIs) in a population of 1,156 intensive care unit (ICU) patients in 24 countries. Multilevel modeling was used to account for variables that differed by country and ICU, as this was a non-representative cohort study. The results by Tabah et al. show only 2 countries without MDR organisms in the participating ICUs (n=7 patients). The overall results of isolated organisms (bacteria and fungi) showed that 47.8% were MDR; the researchers also needed to include categories for organisms resistant to nearly all (20%) or all treatments (0.4%).

Overall, the reviewed studies indicate that patients with HAIs incur increased cost, LOS, risk of readmission, and risk of mortality than patients without HAIs. Studies have shown that bacteria are present on surfaces in hospitals (Clements et al., 2008; Dancer, White, Lamb, Girvan, & Robertson, 2009). Patients in hospitals have MDR organisms (Patel et al., 2012) and HA-BSI infections (Tabah et al., 2012). The implication of the presence of MDR bacteria and HA-BSIs in hospitals is that all patients will be at risk to develop MDR HAIs. The lack of effective antibiotics to treat MDR HAIs will result in exponential increases in costs, LOS, morbidity, and mortality over current levels, making hand hygiene critical in decreasing these negative outcomes.

Hand Hygiene Effectiveness

Hirschman et al. (2001) examined types of hand hygiene and the complications from the insertion of peripheral intravenous (PIV) lines. This prospective study was conducted in 3
hospitals, and 1,132 PIV line insertions were documented. The finding was that hands disinfected with a solution containing alcohol reduced signs of infection in PIV lines better than hands washed with unmedicated soap or not washed at all (Hirschman et al., 2001). The researchers acknowledged that PIV line complications increased with time (in place at the same site), but did not state how this variable was included in the multivariate analysis. Hirschmann et al. included redness and swelling (among others) as signs of infection, so it is possible cases of extravasation were included as infections.

Cromer et al. (2008) directed a study in South Carolina medical center that instituted hand hygiene monitoring observational tool as a means of increasing compliance. Monitoring was completed on 3,002 healthcare workers. Compliance rose from 72% to 90%, and methicillin-resistant *Staphylococcus aureus* (MRSA) HAIs declined 38% (Cromer et al.) The researchers stated that expanded usage of a new skin antisepsis preparation for invasive procedures during the period of the study may have affected the MRSA rate. The facility had decreased MRSA from wounds, as well as the respiratory and urinary tracts, so hand hygiene was still effective against these HAIs.

A time series study, with multiple interventions in 5 categories, was administered in a rural teaching hospital by Kirkland et al. (2012). Hand hygiene compliance rose 46% and the HAI rate decreased 31%. Average monthly observations in the hospital ranged from 244 to 498 (Kirkland et al., 2012). A weakness of this study is that hand hygiene observations were described as being done monthly at a minimum by infection control staff; however, more observations were conducted at the end of the study. For example, in the first year 19 observations were made in one ICU, and 243 observations were completed in the last year of the
study in the same ICU. Although the increased compliance may have been due to the augmented presence of infection control staff, its effect on the decrease in the HAI rate was still significant.

Another study conducted by a team of researchers in a Swiss neonatal ICU (NICU) instituted education interventions and observations to determine the effect on HAIs (Pessoa-Silva et al., 2007). This longitudinal survey allowed for comparison over 3 time periods. There were 5,325 observations on healthcare workers to assess compliance. The researchers found that hand hygiene compliance improved after introduction of the intervention, and risk of HAI decreased in infants who weighed less than 1500g. A strength of this study was that suspected HAIs were analyzed by genotype, and the authors found that infections by related genotypes were diminished after the educational intervention. The decrease in bacteria of related genotypes indicates that the healthcare workers were transmitting less HAIs from patient to patient.

The previous studies show that increasing compliance with hand hygiene recommendations can decrease the rate of HAIs. The methods used varied, but an educational intervention is a typical feature in these programs.

**Behavioral Issues with Hand Hygiene Compliance**

Pessoa-Silva et al. (2005) examined beliefs and perceptions toward hand hygiene of 80 healthcare personnel in a neonatal unit. The population was a convenience sample. The theoretical framework was the TPB. A questionnaire was used to assess intention to comply, as well as attitudes, behavioral beliefs, and perceived control. Internal consistency reliability of the scale items ranged from 0.72 to 0.84. Pessoa-Silva et al. (2005) found that intention to comply was related to perceived control and the subjective norm of the value that superiors placed on hand hygiene. Perceived control in the TPB was modeled after self-efficacy (Ajzen, 1991). There
were varying reasons perceived control was low; working conditions and time were the most commonly given reasons in failure to comply.

DeWandel et al. (2010) developed a questionnaire using behavioral determinants to identify and describe the predictors and factors of hand hygiene noncompliance in ICU nurses. The framework of the questionnaire was taken from Fishbein and Ajzen (Theory of Reasoned Action) and Bandura (SCT). The questionnaire was validated using an expert panel, and internal consistency measured from 0.52 to 0.74. This questionnaire was completed by 148 ICU nurses (twice) in a large hospital in Belgium. Poor self-efficacy and perceived barrier of time were the major determinants associated with noncompliance. A sample self-efficacy item related to accessibility of equipment to perform hand hygiene. Knowledge did not relate to self-reported practice, possibly because responses were influenced by social desirability to inflate compliance. Self-report was an admitted limitation of this study. This convenience sample also had an attrition rate of 20% for the retest, which was done 2 weeks after the initial test.

Research in a large urban teaching hospital tested a multimodal intervention of education, observation, and feedback (Doron et al., 2011). In addition to the multimodal intervention, the researchers used marketing techniques to promote the initiative that fit institutional culture, support from administration, and monthly feedback. Compliance rose to 94% from 72%, and Doron et al. stated that compliance was sustained, although observations decreased over 11 months. The rate of MRSA decreased over time, but the rate of vancomycin-resistant Enterococcus (VRE) was less clearly associated with increased hand hygiene. The researchers posited that VRE decreased, but the graphed data showed large variations in rate. The researchers did not include statistical significance with the HAI rates, but stated compliance increased significantly. Compliance was measured by an observer watching staff before and after
The unrecorded observations should have been tallied to evaluate their potential impact on the compliance rate.

A systematic review of educational interventions for hand hygiene was undertaken by researchers in Britain’s National Health Service (NHS). Cherry et al. (2012) reviewed 30 articles and found that multiple educational interventions worked better than a single intervention. Audit and feedback were two of several elements that were effective at reinforcing the educational offering. The researchers encouraged the use of performance feedback for healthcare workers, as it was associated with increased compliance. Feedback may occur after an intervention or in regular intervals for an extended study. Ultraviolet (UV) light was used in several studies to provide performance feedback; the light is typically paired with a compound that fluoresces. The healthcare worker applies the fluorescent compound, performs hand hygiene, and then uses the UV light to get an appraisal of the performance of hand hygiene (competence). Many studies had an intervention to teach competence, but the outcome measure was compliance. As a result, the researchers were not able to determine the effect of competence in the review, as competence and compliance were judged concurrently. Notably absent from this review was a discussion of how the included studies measured compliance, despite the authors using change in hand hygiene compliance as a primary criteria for inclusion.

A qualitative study used interviews and focus groups to query 65 healthcare workers about why hand hygiene compliance is a problem. The sample was purposive as ICU and surgical personnel were recruited across 5 hospitals. Participants worked at 5 hospitals of varying size in Belgium. Erasmus et al. (2009) found that the entire group of participants felt efficacy beliefs about hand hygiene and the hand hygiene expectations set by senior staff were influential
for compliance with hand hygiene. Additional findings across all participant groups were that hand hygiene is done after tasks considered unclean, and self-protection is an important aspect of compliance. Some participants felt the evidence for hand hygiene to decrease HAIs is not conclusive. Confirmability of the meaning of the data was met by having 2 researchers analyze results, with a third person available to decide disputes.

Interventions in hand hygiene compliance have been subject to Cochrane Systematic Review (Gould, Moralejo, Drey, & Chudleigh, 2010). Gould et al. (2010) found only 4 articles that met Cochrane quality criteria, 2 of which had been in a previous Cochrane Review. A Cochrane Review had previously been done in 2007, so a search was conducted for the years 2006-2009. The authors characterized the quality of intervention studies as “disappointing.” Gould et al. (2010) stated the need for studies with robust rigor in this field.

The beliefs of healthcare workers, including self-efficacy beliefs, can be a barrier to increasing hand hygiene compliance. Self-efficacy beliefs may be related to time or accessibility factors. Interventions which offer education, observation (audit), and feedback have been associated with increases in compliance. The studies in this field often include multiple interventions, lack theoretical basis, and rely on self-report. Multimodal interventions that get repeated over time support higher hand hygiene compliance. Studies that examine multimodal interventions include education with various additional elements: demonstration, self-study, video, or online offering. Specific multimodal interventions have not been identified to be effective; the current state of science in hand hygiene recommends multiple interventions over a single intervention. This area of research has an abundance of atheoretical studies with poor methodology, and most behavioral studies focus on healthcare professionals, not students. It is imperative that research grounded in theory be done with students, so that student and
professional behaviors can be evaluated for change over time and advance the research into poor hand hygiene compliance.

**Nursing Students and Hand Hygiene**

A mixed-methods study done with nursing students in Great Britain (Cole, 2009) presented the problem of inaccurate self-assessment. A survey which examined cognitive items, motivation, and knowledge was used from another source; no reliability or validity data were given. The sample was a convenience sample of 147 senior nursing students, and 14 of those were interviewed for the qualitative piece. Statistics were crudely examined using mode, but of interest was that all students scored themselves a 5 or higher on a 7 point-Likert scale for compliance with hand hygiene. This study only examined self-reported compliance; no assessment was made of actual behavior. Students reported a score of 5 or higher for knowledge of hand hygiene guidelines, but according to the author none of the students had read the guidelines.

Waltman, Schenk, Martin, and Walker (2011) conducted a study using an exploratory descriptive survey. Nursing students in their junior year (75) taking a research course comprised the sample. Three surveys asked students to self-report knowledge, opinions, and practices. The surveys for opinions and practices had previously been measured for internal consistency at 0.87 and 0.76, respectively. Waltman et al. reported testing the knowledge survey for validity and clarity, but did not state the results. Waltman et al. administered the surveys after the students had engaged in monitoring of healthcare workers at a clinical site.

The opinion survey showed that 40% of students thought hand hygiene could be effective against transmission of acquired-immune deficiency syndrome (AIDS). Sixty-five percent of students reported in the practices survey that the class and monitoring influenced their own
practices. Students worked with an infection control practitioner to assure interrater reliability on the Hand Hygiene Observation Tool, then made observations of healthcare workers on their own. Students made 900 observations, but data from these observations were not reported. Observations appear to have been done as a teaching method. Although students claimed that their hand hygiene practices were influenced, there was no measurement in a clinical setting.

Nasirudeen et al. (2012) used a convenience sample of 431 nurses in Singapore to ask questions related to hand hygiene. There was no validity or reliability data available for this instrument. An interesting finding was that respondents considered internship programs most effective method to teach hand hygiene, followed by practical lab sessions (Nasirudeen et al., 2012). Respondents found lectures to be the least effective way to teach hand hygiene. Nasirudeen et al. found that 66.3% of the respondents reported themselves to be 90% or more compliant with hand hygiene guidelines. The researchers found most students (95.4%) believed that a mentor would have a positive effect on their compliance with hand hygiene. Since more than half of the students believed they were extremely compliant with hand hygiene guidelines, and greater than 90% believe a mentor could influence their hand hygiene rate, this suggests disconnected self-assessment.

Van de Mortel et al. (2012) conducted a survey of 1721 nursing and medical students in 4 countries. Sampling procedure was not stated. Respondents were questioned about hand hygiene knowledge, practices, and beliefs (Van de Mortel et al., 2012) The internal consistencies of the subscales of the survey were between 0.73 and 0.88. The survey used SCT to develop the beliefs subscale (Van de Mortel, 2009). Respondents’ increased knowledge and practices scores were associated with the number of teaching methods, and beliefs and practices were affected by knowledge (Van de Mortel, 2012). The researchers found that the perceived curricular
importance of hand hygiene was associated with students’ beliefs and practices. In addition, the researchers noted a relationship between the perceptions of respondents regarding hand hygiene as a means of infection control and their beliefs and practices.

Nursing students may not be able to perform an accurate self-assessment. Monitoring others can influence their own practices. The importance of hand hygiene in the curriculum can affect the beliefs and practices of students. Self-report is a limitation in this field of study, and more work needs to be done measuring nursing students’ behaviors.

Nursing and Simulation

Alinier, Hunt and Gordon (2004) compared 2 groups, one group received simulation in their nursing training, and the other did not. The results of the convenience sample of 67 participants showed the experimental group had a greater improvement in test scores on the Objective Structured Clinical Examination (OSCE). The OSCE is a standardized exam used in Britain, and validity of the simulation scenarios was determined by an expert panel. Students were assigned to treatment groups randomly. Eleven of the learning objectives on the OSCE were psychomotor; this strategy was an effective method of instruction for nursing students learning basic skills.

Christian and Krumwiede (2012) used high-fidelity simulation to test 49 obstetric (OB) nurses’ self-efficacy in obstetric complications. The researchers found that self-efficacy rose significantly, and was maintained at six months. The self-efficacy measurement tool used had an internal consistency of 0.93. Complicated scenarios may need more technologically advanced simulators, but the fundamental result of this study is that simulation can help increase nurse self-efficacy in practical applications of nursing knowledge. The increased self-efficacy among
nurses was sustained at 8 weeks post-intervention. Simulation performance was evaluated but not analyzed.

A mixed methods study utilized simulation as a teaching strategy to evaluate nursing students’ perceptions of self-efficacy, satisfaction, and effectiveness (Sinclair & Ferguson, 2009). The simulations were incorporated into a lecture course of 174 students. The intervention group had 1 hour of a 2-hour lecture replaced by simulation. The topics included adult, child, and mental health. Four out of five simulations resulted in significantly increased self-efficacy scores. A previously developed instrument was used, and was modified based upon the competencies in the simulation. The instrument had a known reliability of 0.97, and was validated after modification by content experts. The instrument was not retested for reliability after modification (Sinclair & Ferguson, 2009). Students in the experimental group had higher ratings of satisfaction and effectiveness than the control. Twelve students from the experimental group participated in a qualitative reflection, and they reported more confidence with their nursing practice.

Simulation has been used to examine patient safety behavior in student nurses. A study by Gantt and Webb-Corbett (2010) measured hand hygiene and patient identification in clinical scenarios. The convenience sample of senior nursing students (n=110) participated in 30 minute simulation scenarios that covered 2 or 3 nursing skills. Patient safety behaviors were part of every competency checklist. Students failed to perform hand hygiene when indicated 38% of the time (Gantt & Webb-Corbett, 2010). The researchers provided a sample checklist for blood administration and noted that checklists were evaluated for content validity. One limitation of this study is that students received scores for simulation scenarios; simulation for students is
typically used as a safe place to make mistakes. It is possible that the stressor of receiving a score affected students’ ability to perform on the competency tests.

Cook et al. (2013) included 289 studies in a systematic review and meta-analysis of simulation design components. The researchers identified several strategies that were effective in learning outcomes. Some of the strategies with significant effect sizes were repetitive practice, multiple learning strategies, cognitive interactivity, feedback, and longer time (Cook et al., 2013). Repetitive practice was defined as having more than 1 occasion to execute a task. Cognitive interactivity is increasing cognitive involvement through repetition, feedback, variation, or sequencing (Cook et al., 2013). Longer time was training that required more than 1 day of simulation. One strength of this study was that simulation interventions were compared to other simulation interventions, instead of dissimilar interventions. Simulations should incorporate design components that have been found to be effective. None of the studies examined hand hygiene; studies involving nurses included resuscitation, tracheal suctioning, and venous access.

HAIs increase financial expenditures, illness, and death. MDR organisms are becoming more prevalent, thus placing more patients at risk to contract infections which are difficult to treat. Hand hygiene decreases transmission of infection. Self-efficacy is a barrier to effective hand hygiene practices in healthcare workers. Nursing students do not always correctly assess their own hand hygiene practices. Students prefer multiple teaching methods, and beliefs and practices can be affected by knowledge. Simulation can increase knowledge and self-efficacy. Therefore, simulation should be explored as a method to increase knowledge and self-efficacy of nursing students in the practice of hand hygiene.
Conclusion

From a review of the literature, it is apparent the state of hand hygiene science suffers from a lack of rigor. The lack of rigor are: the infrequent use of valid and reliable tools, weak study design, lack of randomization, and avoidance of theoretical framework. A review of compliance studies found only 7 of 96 studies to use a theoretical framework. Cochrane reviewers were only able to include 4 studies of sufficient quality for a review of hand hygiene intervention studies. This thorough review and analysis of the state of the science shows the dire need for studies of strong design and sound theoretical basis.

SCT has been used to examine self-efficacy in simulation studies. SCT states that learning occurs through self-regulation, forethought, self-reactiveness, and self-reflectiveness. These learning stages are incorporated into simulation by monitoring, preparation work, evaluation, performance feedback, and debriefing. SCT will be used as the theoretical framework for the proposed study.

Hand hygiene studies often teach competence, but use compliance as the outcome of interest. The proposed study will teach and assess competence. The intervention will use components of instructional design that have been found effective. An instrument validated for use in nursing students will be used to assess cognitive and affective domains of learning. Since the proposed study will measure the psychomotor domain, the effectiveness of the intervention on the domains of learning can be assessed through advanced statistics. Studies that examine the cognitive and affective learning of healthcare workers in hand hygiene are plentiful, but there are few that evaluate the ability to perform the task.
Chapter 3

Methods

Research Design

This study utilizing the Hand Hygiene Questionnaire (van de Mortel, 2009) will be an experimental pretest-posttest design with a control and intervention group. Participants will be taken from a convenience sample of undergraduate nursing students at University of Cincinnati College of Nursing (UC CON) and then randomly assigned to their respective groups. The pretest-posttest will be longitudinal, with 3 time points for data collection of the instrument. Three time points will allow the effect to be measured to determine if it is sustained over time. A longitudinal study is considered stronger than a cross-sectional study. There will be a posttest only assessment of hand hygiene technique using an ultraviolet fluorescent compound (Glo Germ) and pretest-posttest of hand microbiological contamination for a wide variety of organisms (Lucet et al., 2002).

Pilot testing of the posttest assessment of the fluorescent compound procedure will be done to ensure that the digital pictures under ultraviolet light are clear and distinct. The pretest-posttest microbiological sampling procedure will be pilot tested to ensure that the procedure allows for colony growth.

Participants

This study will examine the impact of a teaching strategy (simulation) on the knowledge, beliefs, and practice of nursing students. The rationale to select NBSN 2001C, Fundamental Concepts and Skills for Nursing Practice students is that these students have not been exposed to previous hand hygiene instruction or clinical experiences. Therefore, the results will be less susceptible to the biases of expectation and recall.
The participants in this study will be sophomore nursing undergraduate students enrolled in NBSN 2001C at the University of Cincinnati. There were 130 students in the 2012 class of NBSN 2001C, and it is expected that there will be similar or increased enrollment for the 2013 class. All participants will be 18 years of age or older. A power analysis calculated using time averaged differences as a model (Diggle, Heagerty, Liang, & Zeger, 2002) showed that at a power of 0.70, significance of 0.5, the total sample size needed is 86 (43 per group) to detect an effect size as low as 0.35. This allows for a total attrition of 33% (non-participants and participants who withdraw).

After University of Cincinnati Internal Review Board approval, participants will be accessed through Blackboard course email, and provided with information about the opportunity to voluntarily participate in a research study the first or second week of classes (depending on the course syllabus). To minimize coercion or influence, participants will be told that research is being conducted independently of their course; they will not benefit or be penalized by their participation; and their course instructors will not have access to their participation status or responses.

Human Subjects Protection

Student participation will be guided by the University of Cincinnati Human Research Protection Program Policy for students, policy number V.02 (2005). The researcher is not an instructor in the course NBSN 2001C. Students’ participation will not influence their course grades. Students in the intervention group will receive the intervention during course week 1; students in the control group will receive the intervention course week 2 after the study has been completed so that all students receive the same educational offering. Students will be advised that participation is voluntary and that they may withdraw at any time.
The hand hygiene component of NBSN 2001C has incorporated multiple teaching strategies in the past. Students have applied Glo-germ, then washed their hands to examine the results under ultra-violet light every year. Students have also watched videos about hand hygiene. This study will measure the effect of a teaching strategy on student learning and beliefs, as well as hand hygiene technique. There is an effort underway to utilize active learning processes at the UC CON. Therefore, class time will not be used for procedures related to the research study as the procedures are teaching strategies that are currently used or encouraged for use. No class assignments will be used for research purposes.

Research data will be stored on the secure research server at UC CON, in the dissertation committee chair’s section. The dissertation chair and student researcher will be the only personnel to have access to this data through use of a password. Completed paper copies of instruments will be kept in a lockbox in a locked office.

Confidentiality will be maintained through the assignment of a study identification number. All students will be given envelopes containing questionnaires. Hand hygiene assessment by photography and microbiological sampling will be done during lab, therefore students will not be anonymous. The study ID number will be the only student identifier entered into the database.

**Instrumentation**

The Hand Hygiene Questionnaire (HHQ) was developed by van de Mortel (2009) using healthcare students. The 4 subcomponents are a Hand Hygiene beliefs scale (HBS), practice inventory (HHPI), knowledge component (HHK), and importance scale (HIS). In addition, the Marlowe-Crowne Social Desirability scale has been included to identify whether questionnaire answers were influenced by this type of response. The HHQ has been used with nursing and
medical students in Australia, Sweden, Greece, and Italy (n=1721). The instrument’s reliability will be discussed along with content validity, which was the validity addressed by the researcher.

Beliefs within the HBS include self-efficacy and positive beliefs (beliefs about barriers and rewards). The HBS that is a subscale of the HHQ originally contained 37 items, with a Cronbach’s alpha of 0.8 in a sample of 59 student nurses. Mean item-to-total correlations in this sample were 0.37. The two week test-retest coefficient (n=14 student nurses) was 0.85. Socially desirable responses were found to occur with a correlation coefficient of 0.33 (n=45 student nurses). SCT was used as the theoretical underpinning (van de Mortel, 2009). It is scored on a 5-point ordinal rating scale (1=strongly disagree, 5=strongly agree).

The HHPI (subscale of the HHQ) was originally 25 items, and has a Cronbach’s alpha of 0.74 (n=59 student nurses), and contains constructs of the Health Belief Model consistent with SCT (van de Mortel, 2009). The HHPI is scored on a 5-point ordinal rating scale (1=never, 5=always). Mean item-to-total correlation in a population of 59 student nurses was 0.33. Two week test-retest coefficient was 0.79 (n=14 student nurses). Social desirability responding was not significant with this scale. All students will not have been exposed to a clinical setting, therefore 8 items relating to practice will be removed (items 6-13).

The HHK was developed using guidelines from the CDC (van de Mortel, 2009). There were 15 multiple choice knowledge items during initial testing. Content validity for the HHQ was determined by a panel of experts in the field of infection control.

The HIS subscale of the HHQ was originally 25 items, with a Cronbach’s alpha of 0.77 in a population of 59 student nurses. The item-to-total correlation mean was 0.61 (n=59). The two week test-retest coefficient was 0.89 (n=14).
Based upon criteria of items with low correlations, no variance, and relevance, the HHQ was modified by removing or retaining items. The finished instrument has 22 items HBS, 14 items HHPI, 12 knowledge items, and 19 items in the HIS. The Social Desirability scale has 11 items, for a total sum of 78 items in the HHQ. A factor analysis was not done on the scales (personal communication, van de Mortel, 2013). However, if an instrument has strong content validity, then its construct validity may be considered to be bolstered as well (Polit & Beck, 2012).

**Study Research Procedures and Data Collection Process**

Table 1. The following table represents the research procedures and data collection process for this study. The data collection process has 4 phases. Refer to Table 1 for a summary of data collection for each phase.

<table>
<thead>
<tr>
<th>Nursing Skills Lab Day</th>
<th>Control</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHASE I</td>
<td>HHQ pre-test</td>
<td>HHQ pre-test</td>
</tr>
<tr>
<td>Part of course</td>
<td>hand hygiene skills</td>
<td>hand hygiene skills</td>
</tr>
<tr>
<td></td>
<td>HHQ post-test</td>
<td></td>
</tr>
<tr>
<td>Intervention PHASE II</td>
<td></td>
<td>HHS video 6m30s, simulation “5 moments” for hand hygiene</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HHQ post-test</td>
</tr>
<tr>
<td>PHASE III</td>
<td>Microbiological sampling pre-test</td>
<td>Microbiological sampling pre-test</td>
</tr>
<tr>
<td>Part of course</td>
<td>Application of Glo Germ, hand hygiene</td>
<td>Application of Glo Germ, hand hygiene</td>
</tr>
<tr>
<td>PHASE III continued</td>
<td>Photograph hand post-test</td>
<td>Photograph hand post-test</td>
</tr>
<tr>
<td>PHASE III</td>
<td>Microbiological sampling post-test</td>
<td>Microbiological sampling post-test</td>
</tr>
<tr>
<td>PHASE IV – one week later</td>
<td>HHQ post-test, HHS video 6m30s, simulation “5 moments” for hand hygiene</td>
<td>HHQ post-test</td>
</tr>
</tbody>
</table>
Phase I

Students will receive a 45 minute hand hygiene lecture prior to the skills lab component to ensure all students have the same content. This lecture is part of the class, not a study component. The lecture topics are medical asepsis/infection control; standard precautions; and transmission-based precautions. On the day of assigned lab, students will be given envelopes with the HHQ developed by van de Mortel (2009) before the skills lab component on hand hygiene (pretest). The informed consent document will be read by the primary researcher. Students will be instructed to fill out and return the instrument into the envelope (phase I) if they choose to participate. If students choose not to participate, they will be instructed to return the envelope so that their participation status is not identified. All students will listen to the skills lecture on hand hygiene given by the course instructor. Sections of course NBSN 2001C will be cluster randomized using a table of random numbers generated from www.randomizer.org.

Sections randomized to the control will be given the HHQ after the lecture (posttest). Sections randomized to the intervention group will be given the HHQ after the lecture plus intervention (posttest). All sections will be read the informed consent and given the HHQ the following week (3rd time point in the longitudinal study). The HHQ after removal of items is expected to take no longer than 15 minutes, and students will be able to complete in between skills lab activities.

Phase II

The intervention will consist of a 6:30 video Partnering to heal: Teaming up against healthcare-associated infections, by the U.S. Department of Health and Human Services. This program is a video simulation about a patient who gets a HAI. The participants will then simulate “My five moments for hand hygiene” (Sax et al., 2007); the five moments will have been taught in the lecture and reading material. The five moments are part of the WHO Global
Patient Safety Challenge. All students in the experimental sections will receive this intervention even if they do not participate in the study. Students in the control sections will receive this intervention the following week.

Table 2. Scenarios. Students in groups of 4-6 will be given 4 different scenarios.

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Hand hygiene moments 1 (before patient contact) and 4 (after patient contact). Student will adjust item in the manikin environment.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 2</td>
<td>Hand hygiene moment 3 (after body fluid exposure). Student will check wound on manikin.</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>Hand hygiene moment 5 (after contact with patient’s surroundings). Student will be directed to touch item in the area surrounding the manikin.</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>Hand hygiene moment 2 (before aseptic tasks). Student will simulate food preparation for manikin.</td>
</tr>
</tbody>
</table>

Scenario 1 will require patient contact; the level of the participant in the second week in the course means that the direction will be to adjust an item in the ‘patient’ (a manikin) environment for comfort. The participant will be expected to simulate performing hand hygiene before and after contact with the patient (moment 1 and 4). The body fluid exposure simulation (scenario 2) will direct the participant to check a draining wound on the manikin. The participant is expected to simulate performing hand hygiene after exposure to body fluids (moment 3). The third scenario will require the participant to touch an item in the patient’s surroundings. The participant will be expected to simulate performing hand hygiene after contact with the patient’s surroundings (moment 5). The researcher or research assistant will explain hand hygiene before an aseptic task (scenario 4), as the participants will not have learned about aseptic tasks (such as sterile dressing changes) by the time of the simulation. The student will then be expected to
simulate performing hand hygiene before simulated preparation of food (moment 2). See appendix 1 for WHO 5 moments of hand hygiene.

A group of 5 participants should be able to finish these scenarios in 15 minutes. After each participant has had a chance to engage in the simulation, there will be a debriefing. Participants will be able to ask questions and receive feedback from the researcher or research assistant. Debriefing is done in simulation to review the actions and thought processes of the participants so that the future actions of the participants are improved. The debriefing is expected to take no longer than 10 minutes. Participants will be given an envelope with the HHQ (phase 2, 2nd time point).

Phase III

Following the simulation, phase III is the microbiological sampling for hand contamination by common organisms using trypticase soy agar (TSA) as done by Lucet et al. (2002). This phase includes control and intervention groups. The researcher will roll the tip of the index finger of the participants’ dominant hand on the agar plate before and after hand hygiene with soap and water.

Next is the application of Glo-germ lotion by participants in the control and intervention sections. This is done yearly in NCBSN 2001C. While this technique is not correlated with removal of microbes in the literature, it is to be used to visualize effectiveness of the hand hygiene procedure. The participants will be instructed to use 4 drops of Glo Germ for both hands (Turner, Gauthier, Roby, Larson, & Gauthier, 1994). After the Glo Germ has dried, participants will be instructed to perform hand hygiene using soap and water, and blot them dry with paper towels. Then students, with their consent, will have the palm surface their dominant hand
photographed after exposure to UV light (phase III) against a black background in a darkened room (Turner et al., 1994).

The final aspect of phase III will be a second microbiological hand sampling using TSA after participants have performed hand hygiene with soap and water. Participants will be reminded that they may choose not to participate. This will include both the control and intervention sections. The pre and post microbiological sampling and Glo Germ photograph are grouped together due to the risk of contamination of Glo Germ and bacteria from the pens if students sign multiple consents.

**Phase IV**

The final phase (IV), conducted one week later, is the third time point for the HHQ for both the control and intervention sections. Students will be reminded that they may choose to participate and can withdraw at any time. After the control section has finished with the HHQ, they will receive the intervention of the video and participate in the “5 moments” simulation.

**Threats**

Threats to internal validity can compromise research studies (Polit & Beck, 2012). The cause of a variation between groups can be wrongly attributed if threats to internal validity are not minimized. Selection bias will be minimized by randomizing sections of the course to the intervention and control groups. All participants are in the same course, therefore the threat of history will be the same for groups. The threat of maturation will be minimized by obtaining all data points within 1 week; this threat cannot be eliminated as participants are engaged in the learning process. The threat of attrition will be reduced by obtaining data points over 1 week, as well as using active learning methods to engage participants. The testing threat will be minimized by using a control group. The HHQ is the only instrument that will be used, therefore
decreasing the instrumentation threat. Statistical analyses can be used to control for biases, or to determine the extent of bias threats by understanding the relationships between variables.

**Data Analysis**

Data analysis will begin with descriptive data analysis. Validity and reliability of the instrument and its subscales within this student population will be assessed. Four study hypotheses will be quantitatively analyzed, and 1 will undergo qualitative analysis.

Data will be entered into SPSS (v. 21, IBM) after collection, and cleaned before analysis. Analysis will begin at the univariate level and progress to bivariate and multivariate analyses. Descriptive statistics and histograms will be calculated and tabulated. Construct validity of the HHQ for this sample will be assessed through hypothesis testing and principal components analysis of the HBS subscale as described below. Reliability of the instrument in this population of students will be determined by calculating Cronbach’s alpha. The Pearson product moment correlation and Kendall’s tau will be calculated to determine associations among important study variables (Hill & Lewicki, 2007). Scatter plot matrices with smoothed regression lines will be examined to determine the nature of the relationship between variables.

**Hypothesis 1:** Nursing students who receive standard training plus simulation will have increased knowledge regarding hand hygiene behaviors than nursing students who receive standard training.

**Hypothesis 2:** Nursing students who have increased knowledge pertaining to hand hygiene will also have more positive beliefs, as measured by the Hand Hygiene Questionnaire (van de Mortel, 2009).
Hypothesis 3: Nursing students who receive standard training plus simulation will have more self-efficacy beliefs regarding hand hygiene behaviors than nursing students who receive standard training.

Hypothesis 4: Nursing students who receive standard training plus simulation will rate the importance of hand hygiene higher than students who receive standard training.

Data from the HHQ (hypotheses 1-4) will be analyzed using generalized estimating equations (GEE) (Diggle, Heagerty, Liang, & Zeger, 2002). Analysis of longitudinal data often results in non-normal distributions due to correlations within subjects (Ballinger, 2004). Correlated or clustered data must be accounted for when using regression, otherwise regression coefficients and their respective standard errors will be subject to error (Fitzmaurice, 1995). GEEs were used by Liang and Zeger (1986) to test hypotheses within subjects over time. The GEE will be analyzed as part of the generalized linear model (GzLM); the GzLM allows for the analysis of non-normally distributed dependent variables using regression (McCullagh & Nelder, 1989). The GEE permits multiple models to be used to fit the distribution of data in order to calculate correct standard errors (McCullagh & Nelder, 1989). For this study, the time averaged differences between groups will be examined.

The HBS has not undergone analysis for subscales (van de Mortel, personal communication, February 7, 2013); principal components analysis (PCA) will be done to analyze the HBS for this sample. PCA is used to analyze all of the variance in the variables examined (Tabachnik & Fidell, 2007). PCA allows for multiple variables to be condensed into fewer components. This will enable self-efficacy to be analyzed independently of the HBS, as well as to determine the structure of the other belief subscales.
Hypothesis 5: Nursing students who receive standard training plus simulation will have improved hand hygiene technique compared to nursing students who just receive standard training.

The ultraviolet pictures of dominant hands after hand hygiene will be analyzed using Image J (NIH). Image J can calculate optical density, percent of pixels that represent fluorescent areas, and the area of fluorescence within a histogram (Canning, Barford, Sullivan, Wickett, and Visscher, 2009). Image J will allow for the quantification of light in the pictures, which will enable hand hygiene technique and data from the HHQ to be analyzed using a group-difference approach. If the dependent variables are normally distributed, this would result in a series of t-tests. If the distribution is not normal, a modified t-test under the aforementioned GzLM would be done (Clifford, Richardson, & Hemon, 1989).

Microbiological plates obtained from participants will be analyzed qualitatively, with the researcher and a professor determining the degree of growth (low to high), with a second professor to settle any disagreements. If colonies are distinct, samples with distinct colonies will be analyzed quantitatively through counting. If colonies are confluent, then those samples will only undergo qualitative analysis.

Assumptions of the Study

This study assumes that sophomore nursing students will not perform hand hygiene effectively. Another assumption is that students need to practice the five moments of hand hygiene. Some students may work in a healthcare facility and will have received hand hygiene training.
Limitations of the Study

Students may not want to complete the same questionnaire 3 times. They may not want to participate in the imaging or microbiological sampling, which will affect the analysis of the knowledge, affective, and psychomotor learning domains. Students less likely to perform hand hygiene effectively may be less likely to participate.

Summary

This study is a pretest-posttest experiment to examine hand hygiene knowledge and beliefs in sophomore nursing students. This longitudinal study will have 3 time points for participants to complete a Hand Hygiene Questionnaire (van de Mortel, 2009). The GEE model will be used for statistical analysis of the modified questionnaires. Hand hygiene technique will be assessed through the use of Glo-germ and ultraviolet light (posttest only). Image illumination will be analyzed using ImageJ (NIH). Microbiological sampling plates (pretest-posttest) will be assessed qualitatively and quantitatively where possible. The results of the assessment of hand hygiene technique can be used to engage and involve the students to enhance student learning.
Chapter 4

Results

In this chapter, the methods, sample, and data collection will be outlined. The statistics will be discussed starting with univariate, progressing to bivariate and measures of validity and reliability. The results of a principal components analysis will be examined. Finally, inferential statistics outcomes will be summarized and interpreted. Threats and limitations of this study will be explained and discussed.

Sample

There were 131 sophomore nursing students who participated in the research. Demographics of this population were 113 females (86.3%) and 18 males (13.7%). Additional variables could not be considered due to the small population in some age and ethnic groups that would have allowed subjects to be identified. There was 393 questionnaires total, or 131 for each student within the 3 time points. The control group had 66 students and the intervention group had 65 students. Correctly obtained and measureable microbiological samples were obtained for 124 students, with some students failing to complete the test and others with samples not able to be counted due to confluence of colonies. The UV photograph sample set comprised all 131 students.

Methods

IRB approval was obtained and the clinical lab groups were randomized. A set of random numbers was obtained from randomizer.org, and the intervention groups were selected by section number for each clinical lab time from the set of random numbers. There were 6 lab groups, divided into 2 classes at 3 different lab times (Wednesday AM, PM, and Friday AM). Students in the same lab section had the same assignment to control or intervention groups.
Prior to entering the clinical skills lab, students from both sections for each assigned time received the standard lecture (medical asepsis) of 45 minutes. The content covered medical asepsis, standard precautions, and transmission-based precautions. The medical asepsis lecture included material on hospital-acquired infections, the infection cycle, and types and sources of infections. The UC College of Nursing had started an iPad initiative with sophomore nursing students that semester, so each student came to class with an iPad. Students were encouraged to take notes on the iPad while they listened to the faculty member and followed the lecture in PowerPoint in the iPad. Textbooks were loaded onto the iPads, and students had access to all course materials through Blackboard.

Following the lecture, students separated into 2 adjacent rooms by assigned section. Each section had 2 instructors present. The first week of the study was the first week of the semester. Instructors discussed the syllabus; then all students took a short quiz. Following the quiz, the researcher passed out envelopes containing the informed consent and 2 Hand Hygiene Questionnaires (HHQ). The researcher read the informed consent to the students. The IRB required all students to take part in study activities as part of the class, and be allowed to choose to participate in the research via the consent document. A total of 131 of 136 sophomore nursing students chose to participate in the research. Demographic data was not obtained beyond gender to protect confidentiality of students, as some demographic groups would have had 1 member.

Following the study pretest, instructors continued with the other content scheduled for the day. The labs were 6 hours in duration; after 2 hours the instructors were ready for the intervention groups to receive the intervention, consisting of a 6.5 minute video *Partnering to heal: Teaming up against healthcare-associated infections* (US. Dept. of HHS) and 15 minute simulation of the WHO’s 5 moments of hand hygiene. The students watched the video on a large
screen within their assigned lab sections. Next, the researcher read the simulation instructions while performing the simulations. The first scenario directed the student to place the call light in the patient manikin’s hand, and required the student to simulate the use of hand sanitizer before and after patient contact. A dressing with red marker had been placed on each manikin’s right leg prior to class for the second scenario. After the student was asked to check the “wound”, he or she was then required to simulate handwashing.

The third scenario directed the student to retrieve patient items from a bedside cabinet and place in front of the manikin. The student was to simulate using hand sanitizer after touching the items. Simulated food was used for the last scenario. Students needed to open empty box drinks and place in front of the manikin, having simulated hand sanitizer use before preparation. Hand sanitizer dispensers were empty and installed on the wall of the nursing skills laboratory.

The entire lab section engaged in the simulation synchronously in small groups of 2 or 3 students, with each group having a hospital bed with manikin “patient”. Students were instructed to take turns reading the scenarios for the other student and participating in the simulation. Following the intervention, the control and intervention groups rotated through the data collection points of 1) microbiological testing and 2) Glo Germ application, handwashing and hand photograph under UV light. The intervention group had received the standard training, plus video and simulation prior to this testing, while the control group had only received the standard training.

Microbiological testing and UV photography were done in an auxiliary room outside of the lab area. The procedure was developed after consulting with a microbiologist and photographer, and conducting pilot tests. Adequacy of handwashing was measured in two ways: 1) Glo Germ, and 2) bacterial assay. The researcher outlined the procedure before students split
into groups of 2 to 6. Students’ names were written on the agar plates (Carolina Biological Supply; tryptic soy agar, 5% sheep’s blood), and the plate marked and divided in half to differentiate post-handwashing samples. The researcher rolled the index finger of each student’s dominant hand onto the agar, from left to right, using the same technique each time. Students applied 1 pump (0.5ml) of Glo Germ (Glo Germ Company), rubbed hands together until dry (20s), and proceeded to wash their hands with AeroBlue Foam Hand and Body shampoo (Deb USA). Soap without antibacterial additives was used to allow for bacterial growth to detect differences in handwashing technique. Students were instructed to use the handwashing guidelines discussed in class (i.e. warm water, 30 second rub, and disposable towel to dry); however they were not given any prompts to remember the guidelines. After drying, the student’s name was confirmed, and then the index finger of the student’s hand was rolled on the opposite side of his or her agar plate.

Photographs of each student’s dominant hand under UV light were taken following completion of each small group’s microbiological samples. Prior testing of the light showed that 2 eighteen inch black linear fluorescent bulbs (Philips), as well as 1 UV LED flashlight (Abco Tech) were needed to ensure camera focus. The fluorescent bulbs had a peak wavelength of 368nm, while the flashlight peaked at 375nm. The wavelength of UV light used for blacklights is between 320-400nm (Health Physics Society, 2011). The fluorescent bulbs were placed horizontal, forward-facing, and 23 inches away from a matte black board (Elmer’s, 20x30 in.). A table was used to position the black board, tripod, and stands for both fluorescent bulbs in the same manner for each lab section. The flashlight was 17 feet behind the black board, and 5 feet high.
Students were instructed to place their dominant hands in front of the camera (Nikon D3200), which was stabilized on a tripod due to slow shutter speed in low light. The fluorescent bulbs were on either side of the tripod. Photographs were taken with a remote, using a shutter speed of 1/15, aperture 5.6, ISO 1600, and lens 24mm. These settings were selected after consultation with a professional photographer and allowed visualization of the Glo Germ and consistent camera focus. Photographs were saved in RAW. RAW files are a lossless format (Atkins, 2008), meaning that the pixels are not compressed and values changed when the image is saved.

Students were asked to fill out the second HHQ upon completion of the microbiological and UV stations. Envelopes were collected by the researcher at the end of each class. Microbiological samples from Wednesday AM and PM classes were taken to University of Cincinnati Clermont College and placed in the incubator. Samples were incubated at 97.5°C for 22 hours to allow for bacterial growth to remain distinct, before colonies grow together and become obscure. Samples from Wednesday morning were inoculated between 9 and 12 hours before incubation; the other samples had a lag time of 3-6 hours. Samples from Friday morning were transported and incubated in the same manner as the Wednesday samples.

The microbiological samples were removed from the incubator after 22 hours and photographed on a darkfield colony counter. Due to the nature of the blood agar, the colonies could not be illuminated beneath the plate. The samples were photographed with a Nikon D3200, using a tripod 3.5 feet high, and camera lens 4 ¾ inches above the base of the tripod. This had the effect of the camera aimed down at the plate at an approximate 45° angle. A table was used to position the colony counter and tripod for consistency. The Wednesday samples were photographed under fluorescent light at night, and the Friday samples were photographed under
fluorescent light during daylight. Plates were photographed under varying light conditions due to their placement in the incubator at different times of day due to the Wednesday PM clinical. Camera settings were adjusted for the different lighting conditions.

The second week of the course, students in all sections were reminded they could withdraw from the study at any time. To assess study hypotheses longitudinally, the third HHQ (post-posttest) was handed out and students were instructed to complete. Upon return of the questionnaires the control sections were allowed to participate in the intervention. Data collection was complete and data processing ensued.

Colonies visible on the agar plates were counted using the JPEG (Joint Photographic Experts Group) image magnified 0.5x in the software View NX2 (Nikon). A grid was placed over the image, and each cell was counted top to bottom, left to right using a clicker counter. The image was rotated 90° and counted again if count <300 to ensure accuracy. Dense individual cells on grids were recounted if the total colony count was >300.

The UV photographs of students’ dominant hands were converted from 12 bit RAW to 16 bit TIFF (tagged image file format) for analysis in Image J (NIH). Pixel intensity in a 12 bit RAW file has 4,096 brightness levels; the same image taken in 8 bit JPEG file has only 256 levels per pixel (Atkins, 2008). Each image was opened in Image J and the area of the hand was outlined using the selector tool. The measurements taken for each image were the minimum, maximum, and mean gray values; the area; and the integrated density. The integrated density is the product of the area and the mean gray value (Ferreira & Rasband, 2012).

**Analyses**

For the purpose of statistical analysis, data from the HHQ, the microbiological counts, and integrated density were entered into IBM SPSS (v. 21). Student identifiers were removed.
Negative items in the HHQ were reverse scored to calculate total scores for the scales. Data were checked for inaccuracies and SPSS was used to analyze descriptive statistics. SPSS files were converted to Microsoft Excel files for inferential analysis in SAS 9.4 (SAS Institute), in collaboration with a biostatistician. If data were missing from one item on a test, the other two tests were examined, and if the values were the same for that student, that value was imputed for the missing item. This practice did not compromise the results as the missing items were almost exclusively found in the HIS (importance) or HHPI (practices) scales, and values trended to high ratings for all students. Items missing in all 3 of a student’s HHQ tests were left missing.

**Construct Validity**

Construct validity can be measured by having 2 groups (which are different) complete the instrument and conduct hypothesis testing (Polit & Beck, 2012). For the HHQ, mean differences were hypothesized for the scores of the HHK (knowledge), HIS (importance), and HBS (beliefs) scales. Mean differences were not found between the control and intervention groups for the scales of the HHQ, which is discussed in the inferential statistics section. In addition, an analysis of principal components of the beliefs scale yielded several items of complex structure, which were loaded onto more than 1 component (found in PCA section). The validation of this instrument in this population was not established in this population due to failure to find mean differences in the hypotheses.

**Reliability**

Internal consistency was measured by Cronbach’s alpha, which can be found in table 3. Higher values equal higher reliability, with 0.70 considered adequate (Polit & Beck, 2012). Reliability of the HHK (knowledge) quiz was not available from the information regarding the HHQ’s development (van de Mortel, 2009). The overall knowledge scores were binary coded
(correct/incorrect) and the $\alpha=0.29$. The overall $\alpha$ for the HHQ was calculated without the knowledge quiz, and was 0.77; the range for the 3 time points was 0.74-0.79. Cronbach’s alpha was computed for the rest of the scales in the HHQ.

The scales of the HHQ showed adequate reliability (3 of 4 with $\alpha = 0.7$ or $\alpha > 0.7$), excluding the HHK (knowledge) quiz and HHPI (practices) scale. These values can be found in table 3. The HHPI scale (practices) had an overall $\alpha$ of 0.64, with a range of 0.61-0.66. Negative items in the Social Desirability scale were reverse scored and the $\alpha= 0.70$. The range of values for the 3 time points was 0.63-0.78. The HIS (importance) scale had a Cronbach’s alpha of 0.67, and the range was 0.59-0.74. The HBS (beliefs) scale had the highest reliability within the HHQ at $\alpha=0.77$ (0.76-0.81).

**Descriptive Statistics – Univariate**

Table 3. HHQ Scale Descriptives

<table>
<thead>
<tr>
<th>Scale</th>
<th># of Items</th>
<th>Range</th>
<th>Mean</th>
<th>Stan. Dev.</th>
<th>Reliability</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge (HHK)</td>
<td>12</td>
<td>Time 0: C=5-11, I=6-12</td>
<td>Time 0: C=9.15, I=9.11</td>
<td>Time 0: C=1.5, I=1.4</td>
<td>0.29</td>
<td>Multiple choice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time 1: C=3-12, I=5-12</td>
<td>Time 1: C=8.74, I=8.97</td>
<td>Time 1: C=1.6, I=1.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practices (HHPI)</td>
<td>6</td>
<td>Time 0: C=23-30, I=20-30</td>
<td>Time 0: C=28.79, I=28.40</td>
<td>Time 0: C=1.8, I=2.3</td>
<td>0.64</td>
<td>Scale 1=never to 5=always</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time 1: C=25-30, I=22-30</td>
<td>Time 1: C=29.21, I=29.23</td>
<td>Time 1: C=1.3, I=1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time 2: C=24-30, I=26-30</td>
<td>Time 2: C=29.46, I=29.62</td>
<td>Time 2: C=1.3, I=0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Desirability</td>
<td>11</td>
<td>C=0-11, I=0-11</td>
<td>Time 0: C=6.76, I=7.17</td>
<td>Time 0: C=2.4, I=2.1</td>
<td>0.70</td>
<td>True/False</td>
</tr>
<tr>
<td>Importance (HIS)</td>
<td>3</td>
<td>Scored by adding total of all 3 questions.</td>
<td>Time 0</td>
<td>C=10-15</td>
<td>I=12-15</td>
<td>Time 1</td>
</tr>
<tr>
<td>------------------</td>
<td>---</td>
<td>------------------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Time 0</td>
<td>C=10-15</td>
<td>I=12-15</td>
<td>Time 1</td>
<td>C=10-15</td>
<td>I=11-15</td>
<td>Time 2</td>
</tr>
<tr>
<td>Time 1</td>
<td>C=6.71</td>
<td>I=7.37</td>
<td>Time 1</td>
<td>C=6.98</td>
<td>I=7.52</td>
<td>Time 2</td>
</tr>
<tr>
<td>Time 2</td>
<td>C=6.98</td>
<td>I=7.52</td>
<td>Time 2</td>
<td>C=3.1</td>
<td>I=2.4</td>
<td>Time 0</td>
</tr>
</tbody>
</table>

Frequency distribution of the scales was examined for each scale. Regarding the HHK (knowledge) quiz (n=393), 7 questions had 90% or greater correct responses. There were 5 questions with 10-76% split distribution among multiple-choice answers; answers with less than 10% are not noted. Items with more variation have less reliability. The second question in the HHK was a negatively worded question regarding alcohol hand sanitizer, with 2 responses garnering 39% and 55% of answers. Item 6 was another alcohol hand sanitizer question, and responses were split 20% and 76%.

There were 3 items in the knowledge scale split among 3 or more responses. These items have low reliability as answers showed high variation (Polit & Beck, 2012). Item 9 was a negatively worded question with 3 choices, and responses were split at 28%, 38%, and 34%.
Items 11 and 12 were questions about statistics of hospital-acquired infections; the former had 4 choices and the latter 5 choices. Item 11 was split 10%, 36%, and 53%, while item 12 was distributed at 12% (for two responses), 25% and 50%.

As indicated by table 3 and appendix 2, the intervention group had a smaller range of scores, but overall the 2 groups were similar. Both had negative skew; -0.44 control and -0.23 intervention. Negative skew indicates a disproportionate number of high scores (Plichta & Kelvin, 2013), and scores below -0.2 indicate severe skew. Quiz scores at posttest went down for both groups, while the second posttest showed an increase from pretest in mean scores for the control group, and the intervention group returned to baseline. Skewness increased for both groups in the two posttests.

The HHPI (practices) scale used a 5 point scale, from 1 (never) to 5 (always). The number of valid responses was 363. There were 8 questions that were applicable to clinical situations, and sophomore nursing students had not had a clinical rotation at the time of the study. Those questions were removed from analysis due to the large amount of missing data. The overall frequency of the answer 5 (always) for the 6 questions included in analysis was 73.5-91.6%.

The mean HHPI scores were similar for the control and intervention groups, with scores between 28.4-29.6 out of 30 points. Negative skewness was severe to considerable (-1.5 to -3). Severe to considerable skewness indicates that the means would be higher if not for a small number of low scores.

The Social Desirability scale was comprised of 11 true/false statements, and there were 393 responses. Social desirability occurs when responses reflect an expected social norm rather than the subject’s true response (Penguin Dictionary, 2009). Five of the statements were
negatively worded, but this did not affect distribution. Six of the statements had a split distribution between the 2 responses at 30-40% and 60-70%. Four of the statements were divided 16-19% and 81-84%. One statement had a distribution of 25% true and 75% false.

The Social Desirability scale is scored by giving a point for the socially desirable answer. The mean scores for the control group at time points 0-2 were slightly lower than the intervention groups’ mean scores (see table 3 and appendix 2). The skew for both groups at all time points was negative and severe at >-0.2.

The HIS (importance scale) (n=387) contained 3 items on a 5 point scale, coded 1 for strongly disagree and 5 for strongly agree. The responses for 5 (strongly agree) ranged from 78.1-88%. The mean scores for both groups were not less than 14 out of 15 points, which can be compared in table 3 and appendix 2. Both groups had negative skew between -1 and -3, and the histogram shows scores are strongly distributed at the higher end of the scale. Skew >-1 shows considerable asymmetry (Plichta & Kelvin, 2013).

The HBS (beliefs scale) (n=387) was composed of 19 items on a 5 point scale, from 1 (strongly disagree) to 5 (strongly agree). There were 8 negatively worded items, and responses were distributed among all 5 choices between 2.5-38%. Only one positively worded item had a wide distribution between 3 (15.8%), 4 (34.1%) and 5 (49%). The other 10 positively worded items had a frequency response for 5 between 71-92%.

The mean scores for the HBS were similar for both the control and intervention groups, see table 3 and appendix 2. Skewness for the control group was positive and severe (0.327-0.483) for the 3 timepoints. Positive skew means an overdistribution of low scores (Plichta & Kelvin, 2013). The intervention group had severe positive skew (0.4) for time point 1 and severe
negative skew (-0.42) at time point 2. This indicates the distribution of scores changed at the lowest and highest scores (tail of the histogram).

There was an educational effectiveness section that was not part of a scale. Overall, students rated lectures, tutorials, demonstrations, and videos as moderately to highly effective (between 3 and 4 on a 4-point scale). Clinical practice, lab sessions, textbooks, and lecturer’s notes were rated between 2 and 3 on a 4-point scale, which corresponded to mildly to moderately effective. Mildly to not effective techniques (scores between 1 and 2) were computer simulations, websites, research articles, national guidelines and posters. These 18 items were not analyzed further due to large amounts of missing data, including scoring of 0 (not applicable).

Table 4. Microbiological counts and integrated density

<table>
<thead>
<tr>
<th>Technique assessment</th>
<th>Range</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbiological</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precount</td>
<td>C=2-1458</td>
<td>C=522</td>
<td>C=418</td>
</tr>
<tr>
<td></td>
<td>I=1-1503</td>
<td>I =489</td>
<td>I =426</td>
</tr>
<tr>
<td>Microbiological</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postcount</td>
<td>C=7-531</td>
<td>C=210</td>
<td>C=140</td>
</tr>
<tr>
<td></td>
<td>I=6-727</td>
<td>I =254</td>
<td>I =195</td>
</tr>
<tr>
<td>Integrated Density</td>
<td>C=27676.7-92582.3</td>
<td>C=49093.3</td>
<td>C=13359.7</td>
</tr>
<tr>
<td></td>
<td>I=30194.5-90533.3</td>
<td>I =47988.1</td>
<td>I =11615.1</td>
</tr>
</tbody>
</table>

Table 5. Microbiological counts by clinical group

<table>
<thead>
<tr>
<th>Group N</th>
<th>Mean</th>
<th>St. dev.</th>
<th>Median</th>
<th>Range</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wed AM C N=19</td>
<td>Pre</td>
<td>856</td>
<td>299</td>
<td>916</td>
<td>542</td>
<td>1458</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>312</td>
<td>76</td>
<td>291</td>
<td>171</td>
<td>462</td>
</tr>
<tr>
<td>Wed AM I N=20</td>
<td>Pre</td>
<td>699</td>
<td>370</td>
<td>1318</td>
<td>25</td>
<td>1343</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>368</td>
<td>198</td>
<td>680</td>
<td>18</td>
<td>698</td>
</tr>
<tr>
<td>Wed PM C N=23</td>
<td>Pre</td>
<td>643</td>
<td>341</td>
<td>1341</td>
<td>26</td>
<td>1367</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>266</td>
<td>122</td>
<td>460</td>
<td>71</td>
<td>531</td>
</tr>
<tr>
<td>Wed PM I N=20</td>
<td>Pre</td>
<td>730</td>
<td>355</td>
<td>1315</td>
<td>188</td>
<td>1503</td>
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<td></td>
<td></td>
<td>152</td>
<td>256</td>
<td>593</td>
<td>134</td>
<td>727</td>
</tr>
</tbody>
</table>
Table 5 shows the mean pre and postcounts of the microbiological sampling. Histograms of precounts by control/intervention group are in appendix 4, while postcounts are in appendix 5. The different nature of Friday’s microbiological counts can be visualized within these appendices. Appendix 3 shows the reduction in microbial growth within several groupings: control vs. intervention, clinical groups, and control vs. intervention for each clinical lab period.

The UV hand photographs were assessed by integrated density (see table 4). Mean for the integrated density was 48,545, SD 12,489. Density is not in units unless calibrated to a specific standard in Image J. There were data for all 131 students. The microbiological data (n=124) had some missing counts due to 2 students not going to the station, and the other 5 having macro colonies which could not be counted. The mean precount was 506, SD 421. The mean postcount was 231, SD 170; handwashing reduced colony count by approximately half. Most values for all photo and microbiological data had 1 count. Histograms of the hand photograph data by group and time of class (AM/PM) can be compared in appendix 6.

**Bivariate** Scatterplots were done for the subscales of the HHQ, as well as microbiological counts and UV photo analysis data. There were no highly positive or negative linear relationships noted between any 2 study variables. The scatterplots show the visual relationships found in the significant Pearson’s correlation coefficients for the components of the HHQ (appendix 7). The scatterplots in appendix 6 show the similarity between the control and intervention groups’ integrated density values, and the difference in those values between AM
A scatterplot of integrated density and microbiological postcounts by clinical group can be found in appendix 7. This scatterplot shows the lack of a linear relationship between handwashing decreasing bacteria and Glo Germ on hands.

Pearson’s correlation coefficients were run for subscales of the HHQ, as well as the microbiological and photographic data. Weak relationships are at 0.25 or less, while low strength relations are 0.26-0.49 (Munro, 2005). Correlations in the weak range for the Social Desirability scale were HHPI (practices) (0.24, p<0.000) and HIS (importance) (0.125, p=0.014). The Social Desirability scale showed low correlation with HBS (beliefs) (0.277, p<0.000). The HHPI scale showed weak correlation with HIS (0.125, p=0.018) and low correlation with the HBS (0.298, p<0.000).

The microbiological post-handwashing count and integrated density showed a low inverse correlation at -0.333 (p<0.000). The hypothesized relationship was that as bacteria are washed off hands, there is less fluorescence from Glo Germ (positive correlation). It was highly unlikely that as one measure went down, the other would go up. The correlations were run again to identify the correlations in the 6 lab sections. This second iteration resulted in one control section having a significant negative correlation (-0.32, p=0.009); there was no significance in the other sections. It is possible that some students could have contaminated their hands after handwashing, making the integrated density low, and the bacterial count high.

**Principal Components Analysis**

A principal components analysis (PCA) was performed on the 19 item HBS (beliefs) scale for hypothesis 3 testing. Longitudinal data from 3 time points was used (n=387). A sample of 300 cases is considered to be adequate to have reliable correlation measurements (Tabachnik & Fidell, 2007). The sample met the requirement of PCA to have some correlations exceed 0.30
(Schwab, 2003). The correlation matrix computed for the sample met the KMO MSA (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) with a value >0.5 for each variable. The overall MSA was 0.795. Bartlett’s Test of Sphericity for the matrix was less than the level of significance (<0.001), so PCA is appropriate (Schwab, 2003).

Varimax rotation was used because it can decrease factor complexity by redistributing variance within factors and among variables. Rotation is used to link variables to components through manipulation in geometric space (Tabachnik and Fidell, 2007). PCA usually requires several iterations.

Table 6. Initial Eigenvalues First Iteration

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Eigenvalues</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>4.346</td>
</tr>
<tr>
<td>2</td>
<td>2.498</td>
</tr>
<tr>
<td>3</td>
<td>1.405</td>
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<tr>
<td>4</td>
<td>1.176</td>
</tr>
<tr>
<td>5</td>
<td>1.098</td>
</tr>
</tbody>
</table>

Table 7. Communalities First Iteration

Discard items in bold.

<table>
<thead>
<tr>
<th>Communalities</th>
<th>Initial</th>
<th>Extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
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<td>.502</td>
</tr>
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</tr>
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<td>.461</td>
</tr>
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<td>.625</td>
</tr>
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<td>.447</td>
</tr>
<tr>
<td>B7</td>
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<td>.521</td>
</tr>
<tr>
<td>B8</td>
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<td>.482</td>
</tr>
<tr>
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<td>.580</td>
</tr>
<tr>
<td><strong>B10</strong></td>
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<td>.427</td>
</tr>
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</table>
Table 8. Eigenvalues Second Iteration

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Eigenvalues</th>
<th>Total</th>
<th>% of Variance</th>
<th>Cumulative %</th>
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</thead>
<tbody>
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<td>1</td>
<td>2.827</td>
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<td>23.559</td>
<td>23.559</td>
</tr>
<tr>
<td>2</td>
<td>2.274</td>
<td>2.274</td>
<td>18.949</td>
<td>42.507</td>
</tr>
<tr>
<td>3</td>
<td>1.348</td>
<td>1.348</td>
<td>11.235</td>
<td>53.742</td>
</tr>
<tr>
<td>4</td>
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<td>1.017</td>
<td>8.478</td>
<td>62.220</td>
</tr>
</tbody>
</table>

Table 9. Communalities Second Iteration

Discard item in bold

<table>
<thead>
<tr>
<th>Communalities</th>
<th>Initial</th>
<th>Extraction</th>
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</tr>
<tr>
<td>B4</td>
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<td>.519</td>
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<tr>
<td>B9</td>
<td>1.000</td>
<td>.588</td>
</tr>
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<td>B12</td>
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<td>.593</td>
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<tr>
<td><strong>B13</strong></td>
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<td><strong>.397</strong></td>
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<td>.798</td>
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<td>.722</td>
</tr>
<tr>
<td>B19</td>
<td>1.000</td>
<td>.729</td>
</tr>
</tbody>
</table>
The first output revealed 5 eigenvalues >1, see table 6. Eigenvalues >1 indicate the number of components that account for the largest amount of variance (Tabachnik & Fidell, 2007). The communalities are the amount of variance in the variables disclosed in the solution, and values less than 0.5 are discarded (Schwab, 2003). Two iterations of PCA were required to have all communalities >0.5 (tables 7 and 10). There were then 12 variables and 4 components. Variables that load onto more than 1 component correlated >0.4 are considered complex and should be removed (Schwab, 2003). Removed items are shown in table 10.

Table 10. Component Loadings Third Iteration

Discard items in bold, which load onto more than 1 component.

<table>
<thead>
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<th>Rotated Component Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
</tr>
<tr>
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</tr>
<tr>
<td>B1</td>
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<tr>
<td><strong>B2</strong></td>
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<tr>
<td>B4</td>
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<tr>
<td>B5</td>
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<tr>
<td>B7</td>
</tr>
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<td>B9</td>
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<tr>
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<td>B16</td>
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</tr>
<tr>
<td>B18</td>
</tr>
<tr>
<td><strong>B19</strong></td>
</tr>
</tbody>
</table>

Table 11. Communalities Fourth Iteration

Remove bold item.

<table>
<thead>
<tr>
<th>Communalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
</tr>
<tr>
<td>B1</td>
</tr>
<tr>
<td>B4</td>
</tr>
<tr>
<td>B5</td>
</tr>
</tbody>
</table>
Table 12. Eigenvalues Fifth Iteration

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Eigenvalues</th>
</tr>
</thead>
<tbody>
<tr>
<td>B7</td>
<td>1.000</td>
</tr>
<tr>
<td>B9</td>
<td>1.000</td>
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<td>B12</td>
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</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Eigenvalues</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.277</td>
</tr>
<tr>
<td>2</td>
<td>1.362</td>
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</tbody>
</table>

Table 13. Communalities Fifth Iteration

<table>
<thead>
<tr>
<th>Communalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
</tr>
<tr>
<td>B1</td>
</tr>
<tr>
<td>B4</td>
</tr>
<tr>
<td>B5</td>
</tr>
<tr>
<td>B7</td>
</tr>
<tr>
<td>B9</td>
</tr>
<tr>
<td>B12</td>
</tr>
</tbody>
</table>

Table 14. Component Loadings Fifth Iteration

<table>
<thead>
<tr>
<th>Rotated Component Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
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<td>B4</td>
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<tr>
<td>B5</td>
</tr>
<tr>
<td>B7</td>
</tr>
<tr>
<td>B9</td>
</tr>
<tr>
<td>B12</td>
</tr>
</tbody>
</table>

Four complex variables were removed and PCA went through its 4th iteration. One variable had low communality and was removed, see table 11. The 5th iteration of PCA was successful with simple structures and communality >0.5, which are shown in tables 13 and 14.
This left 6 variables loaded onto 2 components. The PCA was complete. The 2 components explained 60.65% of the total variance in the variables (table 12). The variables in the first component were B1, B4, B9, and B12. The variables in the second component were B5 and B7 and both were negatively worded statements. Five of the questions could be associated with self-efficacy as the statements contained the words duty, believe, confident, follow, and perform, but then the PCA would only have 1 component. One question pertained to financial cost in the larger component, which is not associated with self-efficacy.

**Inferential Statistics**

**HHQ Analysis** Hypotheses 1-4 were tested by Analysis of Covariance (ANCOVA). For each score, an ANCOVA of post-test summary scores was performed to evaluate the difference between the intervention and control group, adjusting for pre-test summary scores. Groups were designated by an indicator variable, coded 1 for the intervention group and 0 for the control group. Pre-test measurements were modeled as a covariate. This ANCOVA tests whether the post-test average is the same between groups, adjusting for pre-test values. The ANCOVA method is more powerful than a Change Score analysis (Hedeker & Gibbons, 2006), when the groups are similar with respect to pre-test values, as they are in this study. In the Change Score analysis, the difference between subjects’ post minus pre-test values are regressed on a group indicator variable which is equivalent to regressing the post-test value on pre-test value with a slope of 1, an overly restrictive assumption.

Prior to the analyses, the components of each type of score (i.e. scales) were summed. Total pre-test and post-test total scores were analyzed. Due to missing data for practices scores, the means of observed data were calculated and analyzed.
The analysis assumes a general linear regression model, where the assumptions of normality of total and mean scores follow from the Central Limit Theorem.

Results for each hypothesis are as follows for the study instrument (HHQ):

1. Nursing students who receive standard training plus simulation will have increased knowledge regarding hand hygiene behaviors than nursing students who receive only the standard training.

There was no significant difference between means of the control and intervention groups for the knowledge subscale after ANCOVA. F(1,128)=1.95, p=0.17. One limitation of this subscale was the low reliability in this population. There was too much variance in students’ answers across the 3 time points to determine the effect of the intervention.

2. Nursing students who have increased knowledge pertaining to hand hygiene will have more positive beliefs, as measured by the Hand Hygiene Questionnaire (van de Mortel, 2009).

There was no significant difference between the control and intervention groups for mean beliefs scale scores after ANCOVA. F(1,128)=0.04, p=0.85.

3. Nursing students who receive standard training plus simulation will have more self-efficacy beliefs regarding hand hygiene behaviors than nursing students who receive standard training. F(1,128)=0.04, p=0.85.

There was no significant difference between the control and intervention groups for mean beliefs scale scores after ANCOVA. The PCA results showed many items of complex structure, as well as possible difficulty responding to negatively worded items in this population. A self-efficacy component was not isolated.

4. Nursing students who receive standard training plus simulation will rate the curricular importance of hand hygiene higher than students who receive standard training.
There was no significant difference between means of the control and intervention groups after ANCOVA. $F(1,128)=1.1$, $p=0.79$. Greater variation in answers was needed for there to be a difference between groups.

**Microbiological Count Analysis** The effect of the intervention (primary independent variable) on post microbiological counts (dependent variable) was evaluated by generalized estimating equation (GEE) methodology, assuming a Poisson regression model, which is commonly used to analyze count data, and robust standard error estimation. Other covariates that were included in the model were pre microbiological counts, time of day (AM/PM), and day (Wed/Fri). The SAS procedure PROC GENMOD was used to execute the analysis.

The expected postcount in the intervention group was approximately 22% greater than the expected postcount in the control group after adjusting for precount, time of day (AM/PM), and day (Wed/Fri) ($p=0.02$). The mean for the control postcount ($n=63$) was 210 (SD 140), and the mean for the intervention ($n=61$) was 253 (SD 195). The mean for the control precount was 522 (SD 418), and the intervention mean precount was 489 (SD 426).

The expected postcount in the afternoon was approximately 10% smaller than the expected postcount in the morning after adjusting for precount, group, and day (Wed/Fri), however this was not significant ($p=0.25$).

The expected post count on Friday is approximately 72% smaller than the expected post count on Wednesday after adjusting for precount, time of day (AM/PM), and group ($p=<0.001$).

Results for the fifth and final hypothesis in this study is as follows:

5. Nursing students who receive standard training plus simulation will have improved hand hygiene technique compared to nursing students who receive standard training.
The intervention group had a 22% higher microbiological postcount than expected compared to the control group; the hypothesis is rejected because it was expected to be lower.

**UV Fluorescence Integrated Density Analysis** Analysis of covariance was performed to evaluate differences between control and intervention groups with respect to mean values of integrated density, adjusted for time (AM/PM). A log linear model was analyzed, as the log (base e) transformation improved the fit of the model, compared to the analysis of raw data, as determined by the AIC (Akaike Information Criteria). Data are often transformed to fit a normal distribution (Tabachnik & Fidell, 2007). In this case, the transformation involved computing the exponent to raise base e to each integrated density value (Dorland’s Illustrated Medical Dictionary, 2011). Analyses were executed using the SAS procedure PROC Mixed with robust standard error estimation.

Based on a 5% level of significance, mean integrated density values of groups were not significantly different \[ F(1,128)=0.18, \ p=0.67 \]; integrated density means, however, differed significantly between morning and afternoon \[ F(1,128)=7.51, \ p<0.01 \]. The morning sections (n=88) had a mean integrated density of 50,802 (SD 13,946), and the afternoon sections (n=43) had a mean of 43,925 (SD 6,878).

5. Nursing students who receive standard training plus simulation will have improved hand hygiene technique compared to nursing students who receive standard training. F(1,128)=0.18, \ p=0.67.

There was no difference in the integrated density (from Glo Germ measured by fluorescence) comparing the means of the control and intervention groups.

To summarize, 131 sophomore nursing students participated in a hand hygiene teaching intervention using simulation. A 78-item instrument was administered, and it was hypothesized
the intervention group would do better on the subscales than the control group. Hand hygiene technique was assessed by taking microbiological samples and a hand photograph using Glo Germ illuminated by blacklight. It was hypothesized the intervention group would do better on measures of hand hygiene technique.

Descriptive statistics of the subscales of the HHQ were similar in mean, range, and standard deviation for the control and intervention groups. Correlations were found to be weak between Social Desirability and the HHPI (practices) and HIS (importance) scales. Social Desirability and the HBS (beliefs) scales had a low correlation. For this sample, two subscales of the HHQ had less than adequate reliability, while the others were adequate. Construct validity was not established. Content validity had been determined during the scale’s development (van de Mortel, 2009). PCA of the HBS (beliefs) scale failed to isolate a self-efficacy component.

Inferential analysis was by ANCOVA for the subscales of the HHQ. There were no significant findings; responses on the subscales trended toward high scores and negative items showed high variability. The microbiological sample results from GEE showed the intervention group had a 22% greater postcount after handwashing. The Friday postcount was 72% smaller than the Wednesday postcount. Integrated density values were analyzed in ANCOVA with a log linear model and showed lower density values in the afternoon versus the morning.

**Threats to Validity of Study**

There were several threats to the internal validity of the HHQ, namely history, maturation, testing and instrumentation. History is a threat when events outside of the intervention occur when the intervention is being given and may affect the outcome (Polit & Beck, 2012). The intervention occurred during the first week of class, and the College of Nursing had begun requiring iPads for students in sophomore nursing classes. During the first week,
students and faculty were meeting in focus groups to discuss technology related issues affecting courses. Some students had not worked with Apple computers before and were anxious. Students were encouraged to take notes on their iPads, and for some there was a steep learning curve. Technology related issues may have overshadowed course content, as well as students taking time to read through the HHQ before answering questions. The effects of maturation were an additional concern in this study.

There were 3 different laboratory times, and students in the $2^{nd}$ and $3^{rd}$ labs may have been apprised of the research activities and altered their behaviors. Students on the first day of class felt rushed, and when some had completed the handwashing station it was nearly time to leave. These students still needed to complete the second HHQ. The researcher heard a student ask “What are we supposed to do – this (HHQ) is the same thing?” Another student replied, “I just filled it out exactly the same as the first.” There were some questionnaires where students missed the negatively worded items in the beliefs scale. Fatigue is likely to have played a role in the responses on the second HHQ, which was given toward the end of a 6 hour lab and would have measured the effect of the intervention. Respondent burden (78 items) may have influenced the trend of high scale scores. The effect of the pretest on the posttest includes the threat of testing as well.

Testing means collecting data, and the act of collecting data can change people’s responses (Polit & Beck, 2012). Administration of a questionnaire can change the attitude of students, even if there is no lecture given. Given the trend toward high scores on the HHPI, HIS, and HBS scales, with small standard deviations at pretest, the intervention would need to have a large effect to impact the posttest scores on the HHQ. Simulation of a basic concept is unlikely to have created this effect. Most nursing intervention studies have a small or medium effect (Polit
& Beck, 2012). Testing problems occur more often with questionnaires (Polit & Beck, 2012). Instrumentation was a threat to this study.

Instrumentation threats are not removed if the same instrument is used. In the case of this study, the HHQ was not an adequate measuring tool in the population. The mean HHK quiz scores decreased for both the control and intervention groups at the posttest (table 3). Upon entering the questionnaire data, the researcher noticed patterns of students changing correct answers. When students changed 2 or more answers, the trend was that the total score was often unchanged or (+/-) 1. The HHK (knowledge) quiz was not reliable in this student population with an $\alpha=0.29$. Most of the variability came from questions regarding alcohol hand sanitizer or statistics about hospital-acquired infections.

The HHPI (practices) scale questioned how often the student performed hand hygiene in six different scenarios. The response pattern for “always” was 73.5-91.6%, and the mean was 29.1 out of 30 possible points. This scale’s mean had more socially desirable effects than the Social Desirability scales’ means for this population. The HHPI scale had the most missing data, as students seemed to be thrown off by some of the wording (e.g. “wound”) and made the assumption that the scenario was clinical. The 6 questions retained were pertinent to daily life. The socially desirable responses made the scale invalid in this population. The HIS (importance) scale showed similar high socially desirable responding, with a mean of 14.4 out of 15 points.

The Social Desirability scale had a mean of 7.08 out of 11 possible points. The $\alpha$ for this scale was 0.70, which compared favorably to 0.62, as evaluated in a sample of nursing students by Loo and Thorpe (2000). Although this scale had adequate reliability, there were only weak to low correlations found with the practices, importance, and beliefs scales. In this population,
social desirability responding for hand hygiene practices and importance was not captured by this scale.

The HBS (beliefs) scale showed 2 instrumentation problems; social desirability and negatively worded item confusion. Negatively worded items had a wider distribution than positively worded items. Ten positive items had a “strongly agree” response between 71-92%. The variation between the 3 time point means of the control group was 0.8 and 1.8 for the intervention group on a 95 point scale. It is unlikely that a strong intervention effect could be captured with the pattern of item confusion and social desirability responding seen with the instrument in this population. The HBS did show correlation with the Social Desirability scale at r=0.277, which is similar to 0.33 that occurred at the instrument’s development (van de Mortel, 2009). There were threats to internal validity from the microbiological testing and UV photography as well.

Glo Germ was an instrumentation threat. Melamine is known to fluoresce, but can be made with fluorescent additives (Sigma-Aldrich, 2007). Sigma-Aldrich advertises the ability to modify such resin particles with functional groups (e.g. carboxyls, which are hydrophilic). The origin and functionality of Glo Germ particles is not known. The adherence of Glo Germ lotion to dry spots on the hands indicates hydrophilic action. Dry spots on the hands would absorb more lotion; Glo Germ is 85% lotion and 15% melamine. Another factor that would affect retention of Glo Germ is the chemical environment of the skin, such as the presence of salts which could interact with the Glo Germ compound. Hydration of hands was not controlled for in this study, therefore it is unknown how well the instrument (Glo Germ) measured hand hygiene technique. More information is needed about the functionality of Glo Germ melamine particles before conclusions can be made about other possible confounding factors.
Results of the microbiology analyses showed some differences for groups on Wednesday versus Friday. The microbiological postcount was significantly smaller on Friday because samples were immediately transported to UC Clermont College’s incubator. The main data collection on Wednesday lasted from 8am to 8pm, while Friday collection began at 8am and was finished by 2pm, thus constituting a historical threat because Wednesday AM plates were inoculated up to 12 hours before incubation. Incubation times for both days were the same. This likely affected the size of colony forming units for the Wednesday AM plates.

The Friday postcounts were still significantly smaller when precounts were taken into account. It is possible that the Friday students had been made aware of study activities by Wednesday students, a maturational threat. There are many opportunities to use alcohol hand sanitizer throughout the College of Nursing, and Friday students may have used it due to their increased awareness. It is possible some students may have exhibited the Hawthorne effect; some female students and all males washed their hands in the testing room. There was no male restroom on the ground floor. Female students who washed their hands in a restroom across the hall from the testing station may not have had the same Hawthorne effect, if any; they may also have contaminated their hands on the way back to the testing station from the restroom. A few students were observed to wipe their hands on their scrubs after handwashing and drying were complete.

Another maturational concern for the Friday postcounts comes from the time of day the plates were photographed. Friday postcounts were photographed under fluorescent light and indirect sunlight. Sunlight can cause lens flare, which can reduce contrast (Hess, 2012). It was noted during processing that there was more detail in the Wednesday microbiological photographs with both large and very small colonies, while Friday photographs were mostly
large, round, and cream-colored. This could have been due to reduced time to transport or reduced contrast in the photos, or a combination of both.

In light of the threats of history and maturation to the microbiological testing, the significant finding of the intervention group having 22% more colonies than the control group must be questioned. The difference between the means was 43 colonies; it must be considered that some Wednesday precounts had 1000+ colonies, while just as many Friday precounts were <100 colonies. There are 2 things which greatly affected the validity and reliability of the microbiological results: the likely usage of alcohol hand sanitizer at the CON, and the lack of an incubator at the CON to immediately process agar plates. Controlling these threats would lead to more confidence in equivalent groups, and the external validity of results.

Equivalent groups were questionable in the UV photograph results. The morning sections had a significantly higher mean than the afternoon sections. One possible explanation for this is that students arriving at 2pm have different factors that affect their hands than students arriving at 8am. Glo Germ is an instrument and its manufacturer makes no scientific claims. The ingredients are claimed to be similar in size to bacteria (5 microns), however the simulated germs are plastic and delivered in a lotion. Glo Germ was noted to adhere to areas of dry skin, especially callouses (stratum corneum). Susceptibility factors for dry skin include age >30, >3 washings/hour, and climate (Seitz & Newman, 1988). Dehydration and lotion use affect the dryness of skin. These 2 factors may account for higher integrated densities in the morning group, as afternoon students would have had more opportunities to hydrate with fluids and lotion.
Conclusion

An experimental pretest posttest design was used to test 4 hypotheses concerning knowledge, beliefs, and curricular importance of hand hygiene, and a 5th hypothesis testing hand hygiene technique in a population of sophomore nursing students. The findings did not support a beneficial effect for the teaching intervention given to the intervention group. A variety of factors impacted the reliability of the instruments, as well as the validity of the findings.

The threats observed in the administration of the HHQ in this population included history, maturation, testing, and instrumentation. The microbiological testing was subject to threats of history and maturation. The UV hand photographs were affected by an instrumentation threat. During the handwashing procedure, some students were in a room with the researcher, possibly leading to the Hawthorne effect. Despite randomization to control and intervention groups, it is likely that the totality of the threats affected the equivalence of groups and validity of results.
Chapter 5

Summary

Hand hygiene is a critical patient safety behavior that has been shown to have suboptimal rates in healthcare settings. Due to the importance of hand hygiene in nursing education, this study examined students’ knowledge, beliefs, rated importance, and handwashing technique. An experimental pretest posttest design with a control and intervention group was used to test the effect of a simulation intervention in a convenience sample of 131 sophomore nursing students. Students were cluster randomized by class section. The hypotheses were as follows:

1. Nursing students who receive standard training plus simulation will have increased knowledge regarding hand hygiene behaviors than nursing students who receive only the standard training.

2. Nursing students who have increased knowledge pertaining to hand hygiene will have more positive beliefs, as measured by the Hand Hygiene Questionnaire (van de Mortel, 2009).

3. Nursing students who receive standard training plus simulation will have more self-efficacy beliefs regarding hand hygiene behaviors than nursing students who receive standard training.

4. Nursing students who receive standard training plus simulation will rate the curricular importance of hand hygiene higher than students who receive standard training.

5. Nursing students who receive standard training plus simulation will have improved hand hygiene technique compared to nursing students who receive standard training.

Methodology

A simulation teaching intervention was conducted with a group of 65 sophomore nursing students. The control group contained 66 students. A pretest and 2 posttests (HHQ) were
administered, and pre and post handwashing microbiological samples were taken. There was a post handwashing data point to capture light emitted by a fluorescent lotion applied to students’ hands prior to handwashing. Univariate statistics showed high frequencies of agreement with the maximum value on the scales. Bivariate statistics indicated weak to low correlations with the Social Desirability scale and the practices, importance and beliefs scales. There was more social desirability responding on the HHQ subscales than on the Social Desirability scale. Reliability of the scale was adequate in this population, but the validity was not confirmed.

The hypotheses from this study were all rejected using the inferential statistics ANCOVA and GEE. While the application of Social Cognitive Theory to the simulation intervention in this study was well-conceptualized by role modeling, repetition and reflection, the results did not show a difference between the control and intervention groups. The validity of the HHQ was affected by fatigue, burden, high scores, and item confusion. In addition, given the amount of social desirability responding and negatively worded item confusion, a large effect would have been needed to capture change using the HHQ in this population. Other confounders in this study were a new computer initiative, possible use of hand sanitizer, and unequal time of agar plates to incubation.

Significant findings from this study are the social desirability responding and difficulty with negatively worded items in this population. Moreover, there is a lack of scientific basis for Glo Germ use. The use of Glo Germ as a teaching tool to show handwashing efficacy may give improper feedback to nursing students, especially those with dry hands. Glo Germ was significantly less visible on afternoon photographs, and there was a trend toward reduced afternoon microbiological postcounts, although it was not significant. The factors surrounding
the difference between morning and afternoon skin conditions were not controlled and are areas for future research.

The main conclusion is that the intervention was not shown to change knowledge, importance, beliefs (all measured by the HHQ), or techniques (measured by microbiological sample and UV hand photograph). There was a significantly smaller microbiological postcount found in the Friday lab sections versus Wednesday. There were confounding factors that affected the results of the microbiological testing. The integrated density values of the hand photographs in the afternoon were significantly less than the morning values.

**Suggestions for future research**

The purpose of this study was to use simulation to instruct undergraduate nursing students to increase their knowledge, self-efficacy, positive beliefs, and the rated importance of hand hygiene. Students often overestimate compliance to hand hygiene, as well as their knowledge and abilities (Cole, 2009), findings that were confirmed in this study. Educational interventions can increase hand hygiene compliance over short periods of time (Mathai et al., 2010). Interventions are needed that will affect behavior over longer periods of time, however most hand hygiene compliance studies lack rigor (Erasmus et al., 2010), and do not report behavior change over 1 year. Compliance with hand hygiene guidelines can decrease patient morbidity and mortality, as well as financial costs to the healthcare system – these facts were proven in 1847 (Semmelweis, 1861).

This study did not develop any educational recommendations to teach hand hygiene to nursing students. Multi-focal educational interventions are needed to address compliance to hand hygiene practices, and the effective schedule of reinforcement should be investigated. Extraneous mediating or moderating variables present in educational settings need to be better
controlled to assess the effect of hand hygiene interventions. Additional research is needed to develop a questionnaire reliable in a beginning nursing student population, as social desirability responding was a threat to the validity of this study.

There needs to be an intervention which begins during healthcare education, and continues throughout the career of the provider. The intervention should have a history of success in behavioral science. Two campaigns have proven effective in changing health behaviors: accountability and use of emotion.

As Goldmann (2006) and Dancer (2009) point out, the computer-chip manufacturing and food processing industries have standards for their workers and facilities. Worker violations of standards in these two industries result in consequences because of the financial loss that will be incurred by the company. The problem is that the healthcare industry has not developed adequate standards and consequences; prior to healthcare reform, violations of standards resulted in financial gain due to the need for increased services by patients with HAIs.

Goldmann (2006) has argued the need to balance blaming the system for failure and making individuals accountable in healthcare. He stated that in a well functioning system, a provider leaving the bedside without performing hand hygiene should be treated as a violation, and violations should have consequences. Axelrod (1984) stated that accountability checks must be made on group members for a social system to maintain itself over time.

Anecdotal reports from some experienced nurses support that they could be sent home from clinical because of uniform standards; a second violation resulted in dismissal from the nursing program. Although uniform violations do not result in dismissal today, there are violations of school or hospital standards which will result in disciplinary action for the student. Accountability is how societies deal with violations of unwritten rule and laws.
There have been limited accountability studies in healthcare. Cromer et al. (2004) attempted to enhance accountability by providing an immediate feedback process during daily isolation rounds. The charge nurse was given a written award or alarm for the unit. Clinical directors received the results once a week, and the best rates were published in the hospital newsletter. Reported results included the isolation compliance rising from 19% to 71.5%, which the authors said demonstrated the importance of accountability to decrease MRSA in hospitals.

Morrow, Griffiths, Rao, and Flaxman (2011) used causal attribution to examine staff perceptions on the causes of MRSA. The researchers found that staff believed MRSA to be caused by external (not self) human factors. Teams felt MRSA was avoided due to good team policy and performance, and MRSA was acquired due to situational factors, including work pressures. The authors indicated that staff needed help to assess their perceptions and responses to take ownership of the behavior.

Uchida et al. (2011) conducted a qualitative study about infection prevention in six hospitals. Four themes that came out were the impacts of mandatory reporting, technology, expansion of the role of infection control personnel, and organizational climate. The values within organizational climate included shared accountability. Most respondents shared the belief that infection prevention must involve all personnel within an organization.

These studies demonstrate that accountability is a factor in organizations attempting to decrease healthcare acquired infections. Currently, some organizations measure hand sanitizer or install cameras outside patient rooms to count adherence to hand hygiene guidelines. There is a movement toward accountability now that healthcare organizations are no longer reimbursed for some HAIs. A provision in Tetlock’s accountability model (1999) is that implementation of unfair accountability practices will result in workers spending more effort on ways to undermine
the organization than thinking about how to get their work done. Therefore, research needs to be done on accountability and healthcare workers to find the appropriate methods to increase compliance. Accountability is a model that is familiar to society, and could be used at all stages and levels of healthcare. Another model that may prove useful is the use of emotion.

Meanwhile, Nicol, Watkins, Donovan, Wynaden, and Cadwallader (2009) used grounded theory to explore infection prevention practices of healthcare professionals. They found that the largest influence on hand hygiene was vivid experience. Individual experiences were considered to have a positive effect on hand hygiene compliance due to the emotional impact. The researchers expressed the belief that exposure to adverse outcomes by a story, as well as a video of poor practice or result of poor infection control practice, could be a positive addition to training. Additional findings were that vicarious experiences are used with success in other public health domains. Nicol et al. (2009) used the example of smoking and traffic safety, but this method is also currently used in the U.S. to discourage drug use and driving while intoxicated.

An additional study on emotional impact used the emotion of disgust. Porzig-Drummond, Stevenson, Case, and Oaten (2009) tested the effects of a 3 minute video on hand hygiene with 96 participants. A second experiment used disgust in educational materials placed in a restroom, contrasted with a restroom without the materials. Participants were members of the public. The disgust intervention was significant in increasing hand hygiene rates in both experiments.

There is a singular approach that can be used to monitor accountability and create emotion in the healthcare setting: microbiological testing. Such testing is standard in food manufacturing facilities, and has been suggested for hospitals (Dancer, 2009). Knowledge of the amount of bacterial contamination present in hospitals would enable accountability of
administration and staff. It would allow patients to be confident when choosing a facility for health care. Results of tests would have the ability to create disgust in healthcare staff. Nurses (and students) who realize that *C. difficile* and MRSA are present in the break room, locker room, and possibly resident flora in their own bodies will change their hand hygiene habits. Without the ability to document the problem, nursing students will continue to be trained with fake germs and fail to internalize the danger of the pathogens they encounter.

**Conclusion**

Unfortunately, the record of hand hygiene educational interventions sustaining an increase in compliance is poor. Findings from this study showed high social desirability responding, which was an obstacle in analyzing the effect of the intervention. There is a dire need for hand hygiene studies to test multi-focal interventions and adequately control extraneous variables. An instrument reliable and valid in beginning nursing student populations needs to be developed.

The high social desirability responding in a population of nursing students who have not been to clinical rotations gives pause as to whether the true effect of an intervention can be assessed by a behavioral instrument in this area of study. Accountability and emotion have been effectively used to promote compliance with healthy behaviors, and are a possible avenue for future research in this area.

Healthcare organizations have only recently been held accountable for some HAIs by the absence of reimbursement by Medicare. Employees of other industries that rely on sanitary conditions face a consequence when they fail to meet standards. Healthcare organizations have started to use accountability in the form of public feedback on compliance with infection
prevention measures, but the industry has not developed a standard or usual practice to increase accountability.

Education that creates an emotional impact has been used to discourage unhealthy behaviors in the U.S. Disgust is an emotion that is already a part of compliance; healthcare providers have higher compliance with hand hygiene after patient care than before. Microbiological testing is a method that would increase accountability of organizations and people, as well as have an emotional impact upon dissemination of results. Healthcare providers do not want to work in unsanitary conditions. Ignorance of microbial contamination allows false feelings of safety in work areas, as well as staff break rooms. Patients and healthcare staff deserve to know the extent of the problem in their facilities.
References


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Appendix 1

Abbreviations

CDC: Centers for Disease Control and Prevention

GEE: generalized estimating equations

GNB: Gram-negative bacteria

HAI: healthcare-associated infection

HA-BSI: hospital-acquired bloodstream infection

HBS: Hand Hygiene Beliefs Scale

HHK: Hand Hygiene Knowledge component

HHPI: Hand Hygiene Practices inventory

HHQ: Hand Hygiene Questionnaire

HIS: Hand Hygiene Importance scale

ICD: international classification of diseases

ICU: intensive care unit

LOS: length of stay

MDR: multi-drug resistant

MRSA: methicillin-resistant *Staphylococcus aureus*

OSCE: objective structured clinical exam
PCA: principal components analysis

PIV: peripheral intravenous (line)

SCT: Social Cognitive Theory

SPSS: Statistical Package for Social Sciences

TPB: Theory of Planned Behavior

TSA: tryptic soy agar

UC CON: University of Cincinnati College of Nursing

UV: ultraviolet

VRE: vancomycin-resistant *Enterococcus*

WHO: World Health Organization
Appendix 2 - Histograms HHQ

Histogram HHK

Test Time Point

- Pretest
- Posttest
- Post second

Quiz no. correct

Frequency

Control

C/t Group

Intervention
Histogram HHPI

Test Time Point

Pretest  | Posttest  | Post second

Control  | C/I Group | Intervention

Practices Subscale Total

Frequency
Histogram Social Desirability Scale

Test Time Point

Pretest

Posttest

Post second

Control

C/I Group

Intervention

SD scale score

Frequency
Histogram HIS

Test Time Point

Pretest
Posttest
Post second

Control
C/I Group
C/I Intervention

Frequency

Importance Subscale Total

8 10 12 14 16 8 10 12 14 16 8 10 12 14 16
Histogram HBS

Test Time Point

- **Pretest**
- **Posttest**
- **Post second**

Frequency

Beliefs Subscale score

Control

C/I Group

Intervention
Appendix 3

Reduction in Microbe Growth

By Group
Reduction in Microbe Growth

By Clinical Group
Reduction of Microbe Growth

By Time

Wednesday AM
Reduction of Microbe Growth

By Time

Wednesday PM
Reduction of Microbe Growth

By Time

Friday AM
Appendix 4

Microbiological Precount by Group

Control
Microbiological Precount by Group

Intervention
Appendix 5

Microbiological Postcount by Group

Control
Appendix 6

Histograms

Integrated Density

By Group
Appendix 7

Scatterplots

HHQ

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Appendix 8

Integrated Density and Microbiological Postcount