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TITLE: A Comparison of Simulation Strategies to Promote Patient Safety and Reduce Medical Error

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The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision unless so designated by other documentation.
The goal of this research was to determine how patient safety and the avoidance of medical error can be effectively taught to student nurses in a simulated setting. Three strategies were compared: a) high fidelity (mannequin) b) standardized patient (actor) and c) video platform (virtual). Both the subjects and the research assistants were blinded to the Dependent Variable; the commission of error. Subjects were randomized to each of the three experiments in a crossover design. In each of the four semesters of the study, one group served as a control and were randomized to a one-time experiment, each semester offered one of the three experiments as the control. During the last and fourth semester, all subjects were offered. Medical error was embedded in each of the three experiments.
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INTRODUCTION

The goal of this research was to determine how patient safety and the avoidance of medical error can be effectively taught to student nurses in a simulated setting. Three strategies were compared: a) high fidelity (mannequin) b) standardized patient (actor) and c) video platform (virtual). Both the subjects and the research assistants were blinded to the Dependent Variable: the commission of an error. Subjects were randomized to each of the three experiments in a crossover design. In each of the four semesters of the study, one group served as a control and were randomized to a one-time experiment, each semester offered one of the three experiments as the control. During the last and fourth semester, all subjects were randomized to a one time-experiment and all three experiments were offered. Medical error was embedded in each of the three experiments; the scenarios included distraction.

BODY

Senior nursing students in their final semester were recruited to participate during their “capstone” semester. As one of the largest schools of nursing in the state, we had access to over 200 senior students. The students were asked to participate by faculty who attended a class with the permission of their instructor to brief the students on the time commitment, logistics and provided them with a written consent to participate. Of the students who were asked to participate, 54 participated (80% female, 20% male) over the four semester timeframe. The ages of the participants ranged from 20-30 (mean SD of 25 years). Of the students who actually participated 50% had experienced 25% of the
clinical hours in simulation as a student and 50% had experienced 25% of the clinical
hours in only two (2) clinical rotations (pediatrics and obstetrics)

Once consented, subjects arrived to the lab with no prior knowledge of the
experiment. The lab was designed to keep the subjects separate utilizing a construction
method with exterior halls and soundproofed simulation rooms. Each subject spent up to
15 minutes on the pretest. 15 minutes in the experiment and up to 15 minutes for the post
test.

Subjects were randomized to all three experiments in a crossover design with a
one month “washout”. A consensus of experts agreed on a one-month washout based on
prior experience with teaching/learning strategies. Each of the four semesters included
one cohort of subjects who were only tested one time in a controlled experiment. The
controls were each of the three simulation strategies and the first cohort received a one-
time experience in one of the three experiments.

Research Objective #1: To determine if one of three methods or a combination of
simulation instruction provides greater mastery in patient safety instruction for pre
licensure students.

Initial analysis showed that there was no discernible difference in performance
across semesters. To allow for more statistically meaningful analysis, groups were
aggregated across semesters (Summer 2012, Fall 2012, Spring 2013) based on treatment
order. Table 1 shows the treatment order for each group. Table 2 shows the results for
the average score on the evaluation form (or virtual reality platform) and sample size n;
the percent that committed medical error; and the percent that were distracted from their
task; and the weighted average for each treatment number across treatment types. There
were no distractions for the virtual reality treatment.

<table>
<thead>
<tr>
<th>Table 1: Treatment order for each group</th>
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<tr>
<td>Group</td>
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<tr>
<td>------------</td>
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<tr>
<td>A (control group)</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>D</td>
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| Table 2: Results for each group and each treatment, in chronological order |
|-------------------------------|-------------------------------|-------------------------------|
| Group | Treatment 1 | Treatment 2 | Treatment 3 |
|       | Avg % | % Distracted | Avg % | % Distracted | Avg % | % Distracted |
|       | Score (n) | Med Error | % | | Score (n) | Med Error | % | |
| B     | 50% (8) | 38% | 0% | 80% (3) | 0% | n/a | 70% (5) | 40% | 0% |
| C     | 68% (10) | 9% | n/a | 33% (6) | 82% | 17% | 61% (9) | 33% | 33% |
| D     | 44% (8) | 38% | 50% | 50% (5) | 60% | 40% | 73% (6) | 17% | n/a |
| Overall | 55% (26) | 26% | 25% | 49% (14) | 57% | 27% | 67% (20) | 30% | 21% |

There appears to be either no change or an improvement in participant score between treatments 1 and 3; however, there may be an increase in medical error. There is not enough evidence to conclude there is a statistically significant difference overall. The largest apparent difference, between Group D’s first and third treatment scores, falls short at the α = 0.05 level (one-tailed p = 0.08). We will use the α = 0.05 significance level throughout this report unless otherwise noted.

Research Objective #2: To determine if the sequence of three methods of simulation instruction predicts mastery of patient safety instruction for pre-licensure students.

Table 3 shows the results for each group and each treatment, sorted by treatment.
The largest difference in average score is between high fidelity and virtual reality.

The hypothesis that the average score for virtual reality ≥ average score for high fidelity is statistically significance with the one-tailed \( p = 0.026 \).

Medical error appears to be more common in the standardized patient and high fidelity environments than in the virtual reality environment. Both the difference between virtual reality and standardized patient; and between virtual reality and high fidelity are statistically significant, two-tailed \( p = 0.03 \) and \( 0.004 \), respectively.

Because participant results for specific treatments are being combined across treatment numbers, the comparisons above may be obscuring actual differences, or conflating them with other factors. We next examine the differences in treatments using the control groups and only observations from the first treatment for each group.

Table 4 summarizes the results for all participants, including control groups, being exposed to a treatment for the first time, across all semesters.
Table 4: Results for each treatment across control groups and first treatments for all groups, across all semesters.

<table>
<thead>
<tr>
<th></th>
<th>Standardized Patient</th>
<th></th>
<th>Virtual Reality</th>
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<th>High Fidelity</th>
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<tr>
<td></td>
<td>Avg %</td>
<td>%</td>
<td>%</td>
<td>Score (n)</td>
<td>Med Error</td>
<td>%</td>
</tr>
<tr>
<td>Overall</td>
<td>50% (13)</td>
<td>38%</td>
<td>31%</td>
<td>71% (18)</td>
<td>6%</td>
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</table>

The results closely mirror those that compared all treatments from Groups B-D. The order in which treatments are administered seems to have less of an impact than the treatment itself.

The difference in average score between virtual reality and high fidelity is statistically significant, two-tailed p = 0.04. No other differences in scores are significant (p = 0.67 for standardized patient and high fidelity; p = 0.13 for standardized patient and virtual reality).

The possible difference in medical error between standardized patient and high fidelity is not statistically significant (p = 0.71). The difference in the percent distracted between standardized patient and high fidelity is also not statistically significant (p = 0.15).

Overall, 25 instances of medical error occurred across a total 74 observations.
Research Objective #3: To determine if prior exposure during training simulations can predict how students will perform relative to non-participants on a final simulation.

The subjects were chosen from a population of last semester Senior nursing students over a two year period. The first two semester subjects were exposed to 25% of their clinical training hours in simulation across two disciplines (pediatrics and obstetrics). The last two semester subjects were exposed to 25% of their clinical training hours ACROSS their entire curriculum. All subjects are required to take a final comprehensive exam as part of their graduation requirements.

The Health Education System Incorporated (HESI) Summary Reports provide content area scores that can be used to evaluate curricular strengths and weaknesses. Estimated reliability of the HESI demonstrates coefficients (KR-20) of 0.940 (Morrison et al. 2004). Evidence of convergent validity was obtained by comparing HESI exam scores to other measures of the same constructs. In three as-yet unpublished studies, associate degree nursing (ADN) and bachelor of science in nursing (BSN) faculties that use HESI exams provided evidence of convergent validity for these exams by correlating students’ HESI exam scores with their final course grades and cumulative grade point averages (GPAs). The correlations were statistically significant (P < .01.)

There is no statistically significant difference between HESI scores from Spring 2012 through Summer 2013. The difference in score between the highest and lowest average is 91 points, between the highest and lowest medians is 97 points, on a scale of 0 to 1600.
The following areas (Table 5) had spreads of 150 points or more. It was not possible to conduct significance tests on the individual areas because of lack of standard deviations in the summary data provided.

Table 5 HESI Subcategories

- N1 – Assessment ($\Delta = 178$): max = Sp12, min = Sp13
- N3 – Planning ($\Delta = 155$): max = Su12, min = Sp13
- C1 – Safe Environment ($\Delta = 150$): max = Su12, min = Fa12
- C2 – Management of Care ($\Delta = 170$): max = Su12, min = Sp13
- C3 – Safety and Infection Control: max = Su12, min = Fa12
- C4 – Health Promotion & Maintenance ($\Delta = 149$): max = Su13, min = Sp13
- C10 – Physiological Adaptation ($\Delta = 177$): max = Su13, min = Sp13

*Research Objective #4: To design a rubric/model for safety instruction capable of stratifying average and exceptional performance.*

We were unable to achieve this objective during the two-year study. We experimented with adapting the Lasater Inventory form (Lasater, 2007), but this tool depends significantly on the debriefing phase of any given simulation exercise and due to the need to protect the dependent variable, none of our subjects were debriefed (Appendix D). We also experimented with an observational tool (checklist) in which specific tasks were expected and then evaluated. This form served as the basis for one of our evaluation tools, but we did not achieve the statistical power to truly develop this checklist.
KEY RESEARCH ACCOMPLISHMENTS

- Three simulation experiments were compared in classic crossover study. To our knowledge, this has not been done before.

- A video (virtual platform) was developed in which actual actors were filmed to give a more realistic approach to the experiment. Most studies utilize computer-generated avatars that, in this author’s opinion, appeal more to the “gaming” aspect of simulation rather than a “reality” approach.

- The Dependent Variable was blinded to both the subjects and the Research Assistants who were themselves chosen across a Liberal Arts campus SPECIFICALLY because they did not have a medical background. We believe this lends more credibility to observation without bias.

REPORTABLE OUTCOMES

- Mid-study report was submitted, accepted and presented to a breakout session audience at the International European Simulation Society (SESAM) in Paris, France, January 2013. Appendix A

- End of study summary was submitted, accepted and presented to a plenary session at the Magic in Teaching conference (Irvine, California October 2013). Appendix B

- A final article is currently under development (first draft Appendix C) for submission to the Simulation in Healthcare journal, an international multi-discipline journal with a high Impact Factor (1.64)

- Results of the study will be more formalized and submitted to the International Medical Simulation in Healthcare (American) conference in 2014.

- Educational strategies developed in this study will be utilized in an Inter professional Education Symposium at the American University, Beirut, Lebanon in June, 2014.
CONCLUSION:

Of the three treatments, the virtual reality scenario had the lowest incidence of medical error, especially compared to the high fidelity simulation. There are two possible explanations for this. The first is that the current generation of students, the Millennials, is very comfortable with and adept at technology, which inherently leads to higher performance. Millennials are defined as those individuals who were born in the time period of the early 1980’s to the early 2000’s. The second explanation is that the virtual reality simulation requires only ordinary learning, not transference of content and skills (Cook et al, 2012). In other words, participants in the virtual reality simulation are showing “Understanding” in Bloom’s Revised Taxonomy, whereas the other two simulations require “Applying” of knowledge and skills.

Given the limited sample sizes, it is not possible to draw strong conclusions about the efficacy of high fidelity versus standardized patients. Standardized patient scores and medical error rates are higher than those for high fidelity, but the percent distracted are lower.

We argue that virtual reality simulations would be a good tool during earlier education stages, as students are learning fundamental concepts. After they have achieved understanding and are able to recognize good practice, high fidelity or standardized patient simulations can be employed to assist in knowledge and skill transference and assessment.
With respect to the efficacy of ordering of treatments it is not possible to discern any effects of the ordering of treatments. It may be that sample sizes are too small or that the ordering of treatments is less important than the actual type of treatment.

Several limitation and challenges were encountered during this study. Due to the student’s class schedule, we had several “no-shows” on occasion and even after attempting to contact them to reschedule, we met resistance. The longitudinal design (three experiment times over three months) was on first notion a strong methodology as each subject could serve as their own control, yet the “drop off” rate presented a problem of statistical power.

The goal of this study was to examine the ability to recognize an embedded medication error in three types of simulation. Tables 1 and 2, which organizes the data in terms of the cycle of treatment, yields little to no statistical significance. The data therefore suggest that despite completing a given previous treatment, the nursing students performed equally well in their next treatment in comparison to other students undergoing the same treatment.

Table 3 offers more statistical evidence that virtual platforms produce higher average scores than both high fidelity and standardized patient treatments. With an average score across all three groups of 71%, virtual platforms surpass the average scores of 55% for standardized patient and 47% for high fidelity. Also, medical error seems to be the lowest with virtual platforms with an average rating of 10%, while high fidelity and standardized patient treatments yielded 55% and 47% respectively. In general, these data suggest that for whatever reason, students performed better in a virtual, instead of hands-on, and interpersonal forum.
Table 4 collates the control groups, which were randomized to a single treatment and not asked to return for following treatments, and the first treatments of groups B, C and D. Data show that without any previous exposure and no proceeding exposure to the treatments, students who underwent virtual treatment derived a higher average score than both high fidelity and standardized patient. Virtual treatments also yielded considerably lower medical error percentages. This suggests with the given student demographic, virtual platforms are more conducive for current students than both high fidelity and standardized patient methods.

A reported 44,000 to 98,000 Americans die annually as a result of medical (Benner et al 2002) error. With this knowledge, it is imperative to not only continue the education of health professionals, but to also encourage active, critical discussion of current educational systems in healthcare. It is clear from the data presented in this study that students undergoing what is considered standard nursing education, are presenting low capability in scenarios requiring active application of their knowledge and skills (i.e. Standardized Patient & High Fidelity).

It can be said that today’s generation, in general, has a markedly distinct upbringing in the age of technology. Therefore, we can expect students’ performances in virtual platforms, as opposed to those requiring active application, to be better. However, healthcare, as also true in the military, is not a business of passiveness, but a business of active practice. So the question must be asked as to how can today’s healthcare (or military) educational system confront this issue presented by students of the age of technology. As this study shows, although limited in subjects and therefore conclusions, the use of progressive methods of education, such as high fidelity mannequins and
technology. As this study shows, although limited in subjects and therefore conclusions, the use of progressive methods of education, such as high fidelity mannequins and standardized patients, can be utilized to help reduce medical risk, and improve future healthcare.

Although conclusions point towards virtual/computer based simulation as being the best methodology for medication error recognition, we wonder if the age of the subjects (~20 years) accounts for a greater comfort with technology and we wonder why the standardized patients demonstrated the greatest challenge for this group of subjects. In a careful systematic review and meta-analysis, Smithberger and colleagues (2012) compared technology-enhanced simulation versus other instructional methods; they concluded that standardized patients and real patients had similar effects for all outcomes except process measures of skills. Since the accuracy of appropriate dose and delivery of medication is a complicated skill, one might conclude that our findings are congruent.

Gaba (2012) maintains that we need to mobilize larger resources to provide more definitive answers to the “big questions about simulation” (p.27). We are grateful to the Department of Defense who provided important resources to advance our understanding of how different simulation strategies serve to educate and train novice learners.
REFERENCES


ATTACHMENT A: PRESENTATION – “Comparing Simulation Strategies to Prevent Medical Error in Baccalaureate Nursing Students” to CESAM in Paris 2013
San Francisco, California, United States
University of San Francisco
James V. Kimpo, student
KT Waxman, DNP, MBA, RN, CNL, CENP
Judith Lambton, EDD, RN

SEESAM 2013

Nursing Students Prevent Medical Error in Baccalaureate Comparing Simulation Strategies to Change the World from Here
No disclosures.
University of San Francisco
School of Nursing and Health Professions

Founded in 1954, USF School of Nursing was the first private university nursing program in California. In the 1980s, the school began offering graduate degree programs. In 2007, the school opened the first Doctor of Nursing Practice degree in California. Master's degree in Clinical Simulation was launched in 2014.
Technology Research Center (TATRC)
Defence Telemedicine and Advanced
The United States Department of
Research Funded by
A simulated setting.

Medical error can be taught effectively to student nurses in

To determine how patient safety and the avoidance of

Research Goal
A Moral Obligation For Sound Research

Suggested by Ziv who takes the position that patients are “not commodities to be used as conveniences of training.” This research was based on Weinger’s model that guides simulation research based on successful models from pharmacology.
Strategies Compared Three Simulation

1. Virtual (computer-based)
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3. High-fidelity manikin
On the ability to recognize

...medication error embedded into the three simulation exercises.

The medication orders were embedded in a series of "tasks" and

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On the ability to recognize
Program in San Francisco.
Final semester senior nursing students in a Baccalaureate
Subjects were...
Nursing.

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Last cohort received a one-time experience in each of the controls were each of the three simulation strategies and the experiment; the only tested one time in a “controlled” experiment, the subjects who included one cohort of subjects who.

Each semester (4 total) included one cohort of subjects who.

Month “washout”.

To all three experiments in a crossover design with a one.

All subjects were randomized.
standardized patient was the LEAST effective
high-fidelity was 50% effective
virtual was the most effective

Results demonstrated that:

Four Semesters (two years)

N=54

Comparison of teaching/learning strategies
Should seniors concentrate on standardized patients?

Should junior-level students utilize high-fidelity platforms?

Should we "start" simulation in sophomores on a virtual university?

How are we educating our baccalaureate students at our implications?
headline in Atlantic Cities (February, 2013)

their computers or smartphones

they would give up their cars before giving up based platforms

They are certainly more engaged in social media/computer

Twenge (2006) believes they are more entitled

Is Are the "Millennials" different as learners?
Losing their car (28 percent).

Nearly two in three (65 percent) of Millennials say losing their phone (30 percent) or computer (35 percent) would have a greater negative impact on their daily routine than them in person.

Nearly half (47 percent) of Millennials sometimes choose to spend time with friends online instead of driving to see them in person.

Nearly three quarters (73 percent) of Millennials would rather shop online than drive or ride public transit to the store.

KRC Research (December 2012)
use social networking several times per week

47.2 percent of those 25 to 29
76.9 percent of people ages 20 to 24 and
An estimated
early use of technology.

natives” due to their fluency with and
describe millennials as “technology
Schoolboy and colleagues (2005)

How different are they?
critical thinking, problem-solving, and teamwork/collaboration professionalism leadership communication

You need to hone your skills in:

seek in college graduates. The results suggest that students
readiness, recently published surveys on what employers
(NACE) and a consortium of organizations on workforce

The National Association of Colleges and Employers

How to adapt?
Thank you

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Judith Lambton, EdD, RN
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Weisinger MB (2010). The Pharmacology of Simulation: A

References
ATTACHMENT B: PRESENTATION – “Exploring Simulation Strategies for Best Practice in Teaching Medication Error Recognition” November 2013
San Francisco, California
University of San Francisco
KT Waxman, DNP, MBA, RN, CNE, CENP
Judith Lambton, EdD, RN

Magic in Teaching, November 2013

Medication Error Recognition
Best Practice in Teaching
Exploring Simulation Strategies for

Change the World from Here
University of San Francisco
No disclosures.
Clinical Simulation in 2014
Launching Master’s degree in California
Doctor of Nursing Practice degree
In 2007, the school opened the first offering graduate degree programs
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School of Nursing was the first private founded in 1954, USF school
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Subjects were...
Nursing: Sophomore Bachelor's Students in Programs OTHER than Research assistants were...
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early use of technology.
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school" (2005)

How different are they?
critical thinking, problem solving, and teamwork/collaboration.

Professionalism, leadership, communication.

How to adapt?
WE WILL CARRY ON
Thank you
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conceptual framework to inform progress in simulation.

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ATTACHMENT C: Best Practices in Simulation
Exploring Simulation Strategies for Best Practice in Teaching Medication Error Recognition

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e-copy held by KTW
Abstract

Healthcare simulation education can contribute to students understanding of the significance of patient safety, specifically medication error recognition. To determine how patient safety and the avoidance of medication error can be taught effectively to student nurses in a simulated setting, we designed a study to compare three simulation strategies: virtual (computer-based), standardized patient and a high-fidelity mannequin. Our study examined the ability to recognize an embedded medication error in all three simulation exercises. The data included 55 senior nursing students from a baccalaureate program over four semesters. Results showed that students did best in recognizing medication error with the video platform. There was a correlation between the students who had experienced 25% of their curriculum practice hours in simulation and those who did not. Simulation is an excellent methodology to teach students medication recognition; the exact medium of simulation depends on the age of the students and the types of simulation available in the lab.

Key words: simulation, medication error, high-fidelity, standardized patient, video
Background and Introduction

Administering medications is a complex task. Patients depend upon the knowledge and expertise of those who order medications and those who administer them. Administration of medications in a hospital setting is a daily occurrence; every nurse administers at least one medication for every patient, every day.

An Institute of Medicine (IOM) report concluded that at least 1.5 million preventable medication errors occur each year in the United States (not including errors of omission) and on average a hospitalized patient is subjected to more than one medication error each day.

Educating nursing students on the importance of safe medication administration before they are employed as staff nurses is imperative and simulation plays a vital role in this education. There is a strong consensus that collaborative practice between physician and nurse should result in a concert of the right patient, drug, dose, route, and time, and documentation. This is not an error proof strategy.

Simulation is an innovative teaching method that is being utilized in healthcare education, and is a proven teaching strategy. Ziv and colleagues suggest that patients are “not commodities to be used as conveniences of training”; clinical educators in both Medicine and Nursing are tasked with developing novel strategies to educate the novice learner while protecting patient safety. While many simulation programs have proliferated across the country and globally, we do not yet fully understand the dose, frequency or appropriate amount of simulation that is appropriate to replace or enhance the traditional model of “guild” learning seen in traditional clinical education.
With the increased sophistication of simulation equipment, and the growth of simulation centers and research programs, curriculum development in simulation-based education has become a priority. Gordon et al suggest that if simulated cases can recreate the cognitive dynamics of real encounters, then important educational moments can be controlled and efficiently replicated in a safe environment.

In current healthcare settings, the opportunity to learn is restricted by: a) the availability of clinical learning opportunity b) the competition among different levels of education (doctors, nurses, paramedics) to learn in situ and c) the financial and emotional cost (both to patient and health care providers) of medical error on the part of novice learners. Patient safety concerns have shaped the way in which students can interact with patients at the bedside, and the way in which educators now view the “clinical learning lab”. Ziv et al take the position that the use of simulation, wherever feasible, conveys a critical educational and ethical message to all: patients are to be protected whenever possible and they are not commodities to be used as conveniences of training.

The situation now exists, that it is not if simulated learning is effective, but when to use it, how to do it and how to evaluate its impact. Weinger offers a conceptual framework to guide simulation research by incorporating past successful research models from pharmacology. Recent work by Smithberger et al compared the effectiveness of three learning strategies: simulation-based, problem-based and standardized patients in pharmacy doctoral students; this appears to be one of the first attempts study different educational approaches in a randomized study.
Our study compares one simulation format with another using different levels of fidelity, different combinations of simulation techniques and different instructional techniques as a way to determine "dose-effect," "dose timing" and "drug-drug relationships."

Continuing with the notion of a pharmaceutically-based model, crossover studies achieve clarity as each subject serves as his or her own "control.” Nearly all crossover designs have "balance," which means that all subjects should receive the same number of treatments and that all subjects participate for the same number of periods. In most crossover trials, in fact, each subject receives all treatments. Adapting Weinger’s model using crossover methodology may inform and guide a research agenda that advances the question: which simulation strategy best achieves a given outcome?

This research attempts to explore patient safety as an outcome (referred to here loosely as the dependent variable) when different simulation strategies (high fidelity, standardized patients and virtual simulation) are presented (independent variable) to the novice learner. Spross and Baggerly have identified key competencies in several domains of healthcare practice. Working within these domains, systematic and human factor errors will be embedded into the case scenarios that are assigned to three possible experimental situations. Errors were chosen to encompass the three major categories of human operator failure as defined by Rasmussen: 10

- a) skill-based errors: errors that occur during “routine” task
- b) rule-based error: failure to follow protocol
- c) knowledge error: lack of or inappropriate application of knowledge

This Department of Defense (DOD) grant funded study was conducted over four semesters specifically addressing medication error recognition with senior nursing students in a
baccalaureate nursing program at a private university in San Francisco, California. The study was designed to determine how patient safety and the avoidance of medical error can be taught effectively to student nurses in a simulated setting. The study investigated which simulation methodology worked best in medication error recognition: virtual (video platform), high-fidelity simulation (mannequin) or standardized patient (actor).

METHODS

Design

A potential medication error was embedded into each of the three simulation scenarios written by the design team. The content of the scenarios was validated by three (3) experts.

The medication orders were embedded in a series of “tasks” and “distractions” that included assessment and vital signs. All subjects were randomized to all three experiments in a crossover design with a one-month “washout.” The washout period was determined by the content experts to be sufficient for subjects to “forget” the prior experiment. Each semester (4 total) included one cohort of subjects who were only tested one time in a “controlled” experiment; the controls were each of the three simulation strategies and the last cohort received a one-time experience in each of the three experiments. The study utilized a randomized, crossover double-blind design.

Subjects were consented to the study as “participating in a study comparing simulation strategies”; they did not know the dependent variable (medication error). The Research Assistants (RA) were recruited from a pool of undergraduate students across a liberal arts campus with nursing students excluded in order to achieve a “naïve” pool of RA’s. The RA’s were oriented to the study design but were not informed of the dependent variable (medication error). None of the faculty investigators participated in the data collection.
Subjects completed a pre test that measured the cognitive domain; the tests were written and validated by three (3) content experts and were tested on the same group of eleven (11) participants prior to beginning the study. Subjects were introduced to each of the three (3) experiments and were given fifteen (15) minutes to complete the assignment. Each simulation was stopped at: a) fifteen minute mark or b) when the student discovered the potential medication error and reported it to someone.

The mannequin (high fidelity) experiment was an adult patient who had undergone abdominal surgery and was complaining of pain and hunger. The medication order was for 100 mg of Lasix IVP; which exceeded the appropriate dose. A telephone was available to call the physician.

The Standardized Patient (SP) experiment included an actor who had a long-standing history of asthma and had multiple complaints throughout the time period. Prednisone was ordered, but the patient stated that he “could not swallow pills”. A pill crusher was available in the patient’s medication tray along with the Prednisone tablets. A syrup of Prednisolone was also available. The subjects were to decide which medication was appropriate. A telephone was available to call the physician. Both the high-fidelity and standardized patient experiments were videotaped.

The virtual (computer-based) simulation was designed by three content experts and consisted of a videotaped sequence in which the subjects were required to then make a “correct” choice of one of three videotaped approaches. The virtual platform was housed on a Blackboard™ site, one that each student had familiarity and login access. There were five video-questions; the answers could be accessed by the faculty investigators.
Participants were classified as to whether they: a) committed a medical error and b) whether they were distracted from the important task they were to complete. Medical error was defined as the wrong dose, the wrong medication, inappropriate protocol or being distracted during the allotted time.

**Evaluation tools**

**Materials**

Several evaluation instruments were used in study and included:

a) a ten question pre/post exam (cognitive measure)

b) A self report of satisfaction

c) Performance Checklist (direct observation)

d) The Health Education Systems, Incorporated (HESI) (a pre-board exam)

The knowledge pretest was administered when the subject arrived at the laboratory for their study experience and immediately after the simulation. The 10-item pre and posttest was piloted with one summer group of senior students prior to the beginning of the study. The test showed some issues with repetitive questions and was manipulated from a 13 questions test to a 10 question test. Every semester showed a strong, consistent item analysis (point-Biserial).

The satisfaction survey was given to the participants after all three simulation variations were completed by the student at the end of their study experience. This 29 item survey allowed the participant to self-report on their overall learning effectiveness of the simulation experiences and self-confidence in error recognition and treatment.

To assist the observers who viewed the participant’s video performance, a key competencies checklist was developed by two clinical experts who study medication errors. The sequential checklist was evaluated for satisfactory content validity by 3 experts.
The HESI Summary Reports provide content area scores that can be used to evaluate curricular strengths and weaknesses. Estimated reliability of the HESI demonstrates coefficients (KR-20) of 0.940. Evidence of convergent validity was obtained by comparing HESI exam scores to other measures of the same constructs. In three as-yet unpublished studies, associate degree nursing (ADN) and bachelor of science in nursing (BSN) faculties that use HESI exams provided evidence of convergent validity for these exams by correlating students’ HESI exam scores with their final course grades and cumulative grade point averages (GPAs). The correlations were statistically significant (P < .01.)

This study compared the HESI exam scores for subjects and non-participants in all four semesters and compared the grade point average (GPA) of the study subjects and a select group (consented) of non-participants.

**Participants/Subject recruitment**

Senior nursing students in their final semester were recruited to participate during their “capstone” semester. As one of the largest schools of nursing in the state, we had access to over 200 senior students. The students were asked to participate by faculty who attended a class with the permission of their instructor to brief the students on the time commitment, logistics and provided them with a written consent to participate. Of the students who were asked to participate, 54 participated (80% female, 20% male) over the four semester timeframe. The ages of the participants ranged from 20-30 (mean SD of 25 years). Of the students who actually participated 50% had experienced 25% of the clinical hours in simulation as a student and 50% had experienced 25% of the clinical hours in only two (2) clinical rotations (pediatrics and obstetrics).

**Institutional Review Board**
An application for protection of human subjects was submitted to both the university in which the subjects were students and the Department of Defense, the organization that funded this study. Both Institutional Review Boards gave permission to conduct the study. All of the subjects were consented using the term “this study is set to compare here different simulation teaching strategies”. Thus, the dependent variable (medication error) was not revealed.

Methodology

Once consented, subjects arrived to the lab with no prior knowledge of the experiment. The lab was designed to keep the subjects separate utilizing a construction method with exterior halls and soundproofed simulation rooms. Each subject spent up to 15 minutes on the pretest. 15 minutes in the experiment and up to 15 minutes for the post test.

Subjects were randomized to all three experiments in a crossover design with a one month “washout”. A consensus of experts agreed on a one-month washout based on prior experience. Each of the four semesters included one cohort of subjects who were only tested one time in a controlled experiment. The controls were each of the three simulation strategies and the first cohort received a one-time experience in one of the three experiments.

Results

Initial analysis showed that there was no discernible difference in performance across semesters. To allow for more statistically meaningful analysis, groups were aggregated across semesters (Summer 2012, Fall 2012, Spring 2013) based on treatment order. Table 1 shows the treatment order for each group. Table 2 shows the results for the average score on the evaluation form (or virtual reality platform) and sample size \( n \); the percent that committed medical error; and the percent that were distracted from their task; and the weighted average for each treatment number across treatment types. There were no distractions for the virtual reality treatment.
Table 1: Treatment order for each group

<table>
<thead>
<tr>
<th>Group</th>
<th>1st Treatment</th>
<th>2nd Treatment</th>
<th>3rd Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (control group)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Standardized patient</td>
<td>Virtual reality</td>
<td>High fidelity</td>
</tr>
<tr>
<td>C</td>
<td>Virtual reality</td>
<td>High fidelity</td>
<td>Standardized patient</td>
</tr>
<tr>
<td>D</td>
<td>High fidelity</td>
<td>Standardized patient</td>
<td>Virtual reality</td>
</tr>
</tbody>
</table>

Table 2: Results for each group and each treatment, in chronological order

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
<th>Treatment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg %</td>
<td>% Med</td>
<td>% Distracted</td>
</tr>
<tr>
<td>B</td>
<td>50% (8)</td>
<td>38%</td>
<td>0%</td>
</tr>
<tr>
<td>C</td>
<td>60% (10)</td>
<td>9%</td>
<td>n/a</td>
</tr>
<tr>
<td>D</td>
<td>44% (8)</td>
<td>38%</td>
<td>50%</td>
</tr>
<tr>
<td>Overall</td>
<td>55% (26)</td>
<td>26%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Despite aggregation, Treatment 2 has fairly small sample sizes, making it difficult to draw conclusions; the relatively small samples make drawing strong conclusions inadvisable.

There appears to be either no change or an improvement in participant score between treatments 1 and 3; however, there may be an increase in medical error. There is not enough evidence to conclude there is a statistically significant difference overall. The largest apparent difference, between Group D’s first and third treatment scores, falls short at the \( \alpha = 0.05 \) level (one-tailed \( p = 0.08 \)). We will use the \( \alpha = 0.05 \) significance level throughout this paper unless otherwise noted.

Table 3 shows the results for each group and each treatment, sorted by treatment.

Table 3: Results for each group and each treatment, grouped by treatment

<table>
<thead>
<tr>
<th>Group</th>
<th>Standardized Patient</th>
<th>Virtual Reality</th>
<th>High Fidelity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg %</td>
<td>% Med</td>
<td>% Distracted</td>
</tr>
<tr>
<td>B</td>
<td>50% (8)</td>
<td>38%</td>
<td>0%</td>
</tr>
<tr>
<td>C</td>
<td>61% (9)</td>
<td>33%</td>
<td>33%</td>
</tr>
<tr>
<td>D</td>
<td>50% (5)</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>Overall</td>
<td>55% (22)</td>
<td>41%</td>
<td>23%</td>
</tr>
</tbody>
</table>
The largest difference in average score is between high fidelity and virtual reality. The hypothesis that the average score for virtual reality $\geq$ average score for high fidelity is statistically significant with the one-tailed $p = 0.026$.

Medical error appears to be more common in the standardized patient and high fidelity environments than in the virtual reality environment. Both the difference between virtual reality and standardized patient; and between virtual reality and high fidelity are statistically significant, two-tailed $p = 0.03$ and 0.004, respectively.

Because participant results for specific treatments are being combined across treatment numbers, the comparisons above may be obscuring actual differences, or conflating them with other factors. We next examine the differences in treatments using the control groups and only observations from the first treatment for each group.

Table 4 summarizes the results for all participants, including control groups, being exposed to a treatment for the first time, across all semesters.

Table 4: Results for each treatment across control groups and first treatments for all groups, across all semesters.

<table>
<thead>
<tr>
<th></th>
<th>Standardized Patient</th>
<th>Virtual Reality</th>
<th>High Fidelity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg %</td>
<td>% Med</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>Score (n)</td>
<td>Error</td>
<td>Distracted</td>
</tr>
<tr>
<td>Overall</td>
<td>50% (13)</td>
<td>38%</td>
<td>31%</td>
</tr>
</tbody>
</table>

The results closely mirror those in Table 3, which compare all treatments from Groups B-D. The order in which treatments are administered seems to have less of an impact than the treatment itself.

The difference in average score between virtual reality and high fidelity is statistically significant, two-tailed $p = 0.04$. No other differences in scores are significant ($p = 0.67$ for standardized patient and high fidelity; $p = 0.13$ for standardized patient and virtual reality).
The possible difference in medical error between standardized patient and high fidelity is not statistically significant ($p = 0.71$). The difference in the percent distracted between standardized patient and high fidelity is also not statistically significant ($p = 0.15$).

Overall, 25 instances of medical error occurred across a total 74 observations.

**HESI**

There is no statistically significant difference between HESI scores from Spring 2012 through Summer 2013. The difference in score between the highest and lowest average is 91 points, between the highest and lowest medians is 97 points, on a scale of 0 to 1600.

The following areas had spreads of 150 points or more. It was not possible to conduct significance tests on the individual areas because of lack of standard deviations in the summary data provided.

- **N1 – Assessment ($\Delta = 178$):** max = Sp12, min = Sp13
- **N3 – Planning ($\Delta = 155$):** max = Su12, min = Sp13
- **C1 – Safe Environment ($\Delta = 150$):** max = Su12, min = Fa12
- **C2 – Management of Care ($\Delta = 170$):** max = Su12, min = Sp13
- **C3 – Safety and Infection Control:** max = Su12, min = Fa12
- **C4 – Health Promotion & Maintenance ($\Delta = 149$):** max = Su13, min = Sp13
- **C10 – Physio Adaptation ($\Delta = 177$):** max = Su13, min = Sp13

**Efficacy of treatment type**

Of the three treatments, the virtual reality scenario had the lowest incidence of medical error, especially compared to the high fidelity simulation. There are two possible explanations for this. The first is that the current generation of students, the Millennials, is very comfortable
with and adept at technology, which inherently leads to higher performance. Millennials are defined as those individuals who were born in the time period of the early 1980's to the early 2000's. The second explanation is that the virtual reality simulation requires only ordinary learning, not transference of content and skills \(^{12,13}\). In other words, participants in the virtual reality simulation are showing “Understanding” in Bloom’s Revised Taxonomy, whereas the other two simulations require “Applying” of knowledge and skills \(^{14}\).

Given the limited sample sizes, it is not possible to draw strong conclusions about the efficacy of high fidelity versus standardized patients. Standardized patient scores and medical error rates are higher than those for high fidelity, but the percent distracted are lower.

We argue that virtual reality simulations would be a good tool during earlier education stages, as students are learning fundamental concepts. After they have achieved understanding and are able to recognize good practice, high fidelity or standardized patient simulations can be employed to assist in knowledge and skill transference and assessment.

**Efficacy of ordering of treatments**

As outlined in Sections x and y, it is not possible to discern any effects of the ordering of treatments. It may be that sample sizes are too small or that the ordering of treatments is less important than the actual type of treatment, as discussed in the previous section.

**Limitations/Challenges**

Several challenges were encountered during this study. Due to the student’s class schedule, we had no-shows on occasion and even after attempting to contact them to reschedule, we met resistance. The longitudinal design (three experiment times) was on first notion a strong design as each subject could serve as their own control, the “drop off” rate presented a problem of statistical power.
Discussion

The goal of this study was to examine the ability to recognize an embedded medication error in three types of simulation.

Tables 1 and 2, which organizes the data in terms of the cycle of treatment, yields little to no statistical significance. The data therefore suggests that despite completing a given previous treatment, the nursing students performed equally well in their next treatment in comparison to other students undergoing the same treatment.

Table 3 offers more statistical evidence that virtual platforms produce higher average scores than both high fidelity and standardized patient treatments. With an average score across all three groups of 71%, virtual platforms surpass the average scores of 55% for standardized patient and 47% for high fidelity. Also, medical error seems to be the lowest with virtual platforms with an average rating of 10%, while high fidelity and standardized patient treatments yielded 55% and 47% respectively. In general, this data suggests that for whatever reason, students performed better in a virtual, instead of hands-on, and interpersonal forum.

Table 4 collates the control groups, which were randomized to a single treatment and not asked to return for following treatments, and the first treatments of groups B, C and D. Data shows that without any previous exposure and no proceeding exposure to the treatments, students who underwent virtual treatment derived a higher average score than both high fidelity and standardized patient. Virtual treatments also yielded considerably lower medical error percentages. This suggests with the given student demographic, virtual platforms are more conducive for current students than both high fidelity and standardized patient methods.

A reported 44,000 to 98,000 Americans die annually as a result of medical error. With this knowledge, it’s imperative to not only continue the education of health professionals, but to
also encourage active, critical discussion of today’s educational systems in healthcare. It is clear from the data presented in this study that students undergoing what is considered standard nursing education, are presenting low capability in scenarios requiring active application of their knowledge and skills (i.e. Standardized Patient & High Fidelity).

It can be said that today’s generation, in general, has a markedly distinct upbringing in the age of technology. Therefore, we can expect students’ performances in virtual platforms, as opposed to those requiring active application, to be better. However, healthcare is not a business of passiveness, but a business of active practice. So the question must be asked as to how can today’s healthcare educational system confront this issue presented by students of the age of technology. As this study shows, although limited in subjects and therefore conclusions, the use of progressive methods of education, such as high fidelity mannequins, can be utilized to help reduce medical risk, and improve future healthcare.

Conclusions

Although conclusions point towards virtual/computer based simulation as being the best methodology for medication error recognition, we wonder if the age of the subjects (~20 years) accounts for a greater comfort with technology and we wonder why the standardized patients demonstrated the greatest challenge for this group of subjects. In a careful systematic review and meta-analysis 15 compared technology-enhanced simulation versus other instructional methods; they concluded that standardized patients and real patients had similar effects for all outcomes except process measures of skills. Since the accuracy of appropriate dose and delivery of medication is a complicated skill, one might conclude that our findings are congruent.

Gaba 16 maintains that we need to mobilize larger resources to provide more definitive answers to the “big questions about simulation” (p.27). We are grateful to the Department of
Defense who provided important resources to advance our understanding of how different simulation strategies serve to educate and train novice learners.
References


10) Lee and Pucel, 1998

11) Burke and Hutchins, 2007


ATTACHMENT D: Global Assessment of Student Performance—Lasater Clinical Judgement Rubric
<table>
<thead>
<tr>
<th>Effective Interprofessional Involvement:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjective data:</td>
<td></td>
</tr>
<tr>
<td>Family and friends collect important information with the patient and offer support to the patient when information is lacking.</td>
<td></td>
</tr>
<tr>
<td>Objective data:</td>
<td></td>
</tr>
<tr>
<td>Measures:</td>
<td></td>
</tr>
<tr>
<td>Observation:</td>
<td></td>
</tr>
<tr>
<td>Focuses on one thing at a time and misses other important information.</td>
<td></td>
</tr>
<tr>
<td>Observation:</td>
<td></td>
</tr>
<tr>
<td>Focusses on the most obvious data and misses other important information.</td>
<td></td>
</tr>
<tr>
<td>Observation:</td>
<td></td>
</tr>
<tr>
<td>Recognizes missing important information and focuses on the most obvious data.</td>
<td></td>
</tr>
<tr>
<td>Observation:</td>
<td></td>
</tr>
<tr>
<td>Identifies obvious patterns and focuses on the most obvious data.</td>
<td></td>
</tr>
<tr>
<td>Observation:</td>
<td></td>
</tr>
<tr>
<td>Recognizes patterns and focuses on the most obvious data.</td>
<td></td>
</tr>
<tr>
<td>Observation:</td>
<td></td>
</tr>
<tr>
<td>Assesses important information and focuses on the most obvious data.</td>
<td></td>
</tr>
<tr>
<td>Observation:</td>
<td></td>
</tr>
<tr>
<td>Interactions lead to effective assessment and effective collaboration.</td>
<td></td>
</tr>
<tr>
<td>Observation:</td>
<td></td>
</tr>
<tr>
<td>Patient and family develop meaningful connections and interactions with the patient and their families.</td>
<td></td>
</tr>
<tr>
<td>Observation:</td>
<td></td>
</tr>
<tr>
<td>Patient and family develop meaningful connections and interactions with the patient and their families.</td>
<td></td>
</tr>
<tr>
<td>Observation:</td>
<td></td>
</tr>
<tr>
<td>Patient and family develop meaningful connections and interactions with the patient and their families.</td>
<td></td>
</tr>
<tr>
<td>Observation:</td>
<td></td>
</tr>
<tr>
<td>Patient and family develop meaningful connections and interactions with the patient and their families.</td>
<td></td>
</tr>
<tr>
<td>Observation:</td>
<td></td>
</tr>
</tbody>
</table>

**Effective Nursing Competencies:***

<table>
<thead>
<tr>
<th>Domain</th>
<th>Quarter 1</th>
<th>Quarter 2</th>
<th>Quarter 3</th>
<th>Quarter 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Learner Clinical Judgment Rubric</td>
<td>discard this line and make sense of the text The text is scrambled</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Overall Ratings (Sum of all the dimension scores)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Improvement</th>
<th>Development</th>
<th>Accomplished</th>
<th>Exemplary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation</td>
<td>Opinion and needs external support is needed to improve the current performance. The plan is clear and action-oriented. The goals are measurable.</td>
<td>Satisfactory improvement is observed in evaluation. The plan is clear and action-oriented. The goals are measurable.</td>
<td>Developmental plans are in place to improve. The plan is clear and action-oriented. The goals are measurable.</td>
<td>Exemplary performance is observed. The plan is clear and action-oriented. The goals are measurable.</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>Demonstrates a desire to improve.</td>
<td>Satisfactory improvement is observed in evaluation. The plan is clear and action-oriented. The goals are measurable.</td>
<td>Developmental plans are in place to improve. The plan is clear and action-oriented. The goals are measurable.</td>
<td>Exemplary performance is observed. The plan is clear and action-oriented. The goals are measurable.</td>
</tr>
</tbody>
</table>

### Effective Reaching Involves

<table>
<thead>
<tr>
<th>Nursing Skills</th>
<th>Nursing Skills</th>
<th>Nursing Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is meant to assess and/or perform skills</td>
<td>Most nursing skills could improve</td>
<td>Suitable skills necessary for the position</td>
</tr>
<tr>
<td>Perceptions towards the patient</td>
<td>Perceptions are indicated by the patient. The response is positive and supportive.</td>
<td>Patients to have their needs met, and their responses are respected.</td>
</tr>
<tr>
<td>Interpersonal skills</td>
<td>Interpersonal skills are observed.</td>
<td>Interpersonal skills are developed and observed.</td>
</tr>
<tr>
<td>Communication skills</td>
<td>Communication skills are observed.</td>
<td>Communication skills are observed.</td>
</tr>
<tr>
<td>Ability to cooperate</td>
<td>Ability to cooperate</td>
<td>Ability to cooperate</td>
</tr>
<tr>
<td>Clear thinking skills</td>
<td>Details in prioritization of tasks, decision-making, and organization</td>
<td>Details in prioritization of tasks, decision-making, and organization</td>
</tr>
</tbody>
</table>

### Effective Communicating Involves

<table>
<thead>
<tr>
<th>Self-Eval</th>
<th>Self-Eval</th>
<th>Self-Eval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Eval is required to improve.</td>
<td>Satisfactory improvement is observed in evaluation. The plan is clear and action-oriented. The goals are measurable.</td>
<td>Developmental plans are in place to improve. The plan is clear and action-oriented. The goals are measurable.</td>
</tr>
<tr>
<td>Performance</td>
<td>Performance</td>
<td>Performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Effective Responding Involves

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Beginning</th>
<th>Developing</th>
<th>Accomplished</th>
<th>Exemplary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate</td>
<td>Rate</td>
<td>Rate</td>
<td>Rate</td>
<td>Rate</td>
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</tbody>
</table>