An Analysis of how Additional Simulation Scenarios Affect SRNAs' Cognitive and Psychological Preparedness for Anesthesia Machine Malfunctions in the Clinical Setting

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Abstract

Simulation experiences are a mandatory part of nurse anesthesia programs. Simulations are intended to improve students' skills in a safe environment, but their effects on cognitive knowledge and confidence are not well documented. This study provided 28 student volunteers with additional simulation opportunities. The experimental group participated in additional simulation experiences and the control group did not. Both groups took a pre- and post-test designed to measure confidence and test students' knowledge. The pre- and post-test scores were compared between the two groups. Despite the perceived importance of simulation, no significant relationship was demonstrated between additional simulation scenarios and cognitive improvement. There was also no significant change in confidence levels regardless of simulation participation or frequency.

Introduction

Simulation is an integral part of many healthcare education programs. It provides an environment in which students can practice without the possibility of harming patients. It also enables instructors to evaluate performances they would otherwise be unable to directly supervise. For example, the use of simulation to evaluate students' ability to prepare and trouble shoot anesthesia machine functions. The application of simulation before integration into the clinical field has proven advantageous when encountering common anesthesia machine malfunction situations.

Simulation courses are incorporated throughout Marian University's DNP CRNA program, each with its own syllabus and course expectations. Structured course calendars include one required lab hour weekly. However, many professors stress the importance of additional lab hours, citing them as essential to passing test outs and being prepared for clinical experiences. While many programs offer open lab hours, they are not required at Marian University. These additional hours are often self-taught, overseen by upperclassmen, or lead by faculty. The time students allot to volunteer simulation can make an overall impact on readiness toward student integration into the clinical arena, as demonstrated in their response to common anesthesia machine malfunctions. Despite this, the current course syllabi for first year CRNA students at Marian University do not contain open lab requirements and there is little to no literature available to support voluntary simulation hours. This project attempted to determine if there is a statistical correlation between voluntary simulation experiences and students' readiness to manage common anesthesia machine malfunctions. In addition, this project looks to assess participants overall readiness for integration into the clinical setting based on self-perception. This paper addresses this gap in literature and provides students and professors with data regarding the impact, or lack thereof, regarding extra simulation experiences.

Background

Simulations are utilized by graduate nursing programs throughout America. Regardless of the wide use of simulation experiences, the Council on Accreditation of Nurse Anesthesia Educational Programs, COA, does not have a set requirement for simulation time (COA, 2019). They do, however, allow for certain simulation experiences, such as central line placement, to replace a limited number of clinical experiences. Despite the assumed importance of simulations within CRNA programs, little research is available regarding simulations within the DNP environment. Even less research is available to guide instructors on required practice hours in the simulation lab.

It has been well documented that simulation experiences can improve self-confidence and perceived preparedness for clinical experiences within nursing programs (Basak et al., 2019, Tamaki et al., 2019, Li, J. et al., 2019). Marian University SRNAs are highly encouraged to attend open-lab hours to practice specific skills, such as machine checks and failures, but these are not required by the university nor is a specific number of hours recommended.

Anesthesia machine tests and failure assessments are one of the first skills listed in the simulation curriculum for first year SRNAs at Marian University. Even with the basic familiarity obtained during required lab hours, SRNAs may be ill prepared to respond to anesthesia machine failures during the perioperative period. Loeb et al. (2019) state that misuse or malfunction of the anesthesia machine accounts for 1-2% of lawsuits involving anesthesia personnel. The majority of anesthesia delivery equipment claims, although infrequent, were a result of provider error. In fact, a study by Mehta et al. (2021) found that 85% of claims made regarding anesthesia equipment were due to provider error, and 35% were preventable by paranesthesia machine checks. Such malfunctions can result in very detrimental outcomes for the patient and the anesthesia clinician.

Anesthesia machine and equipment malfunctions are often unpredictable. Therefore, diligence must be taken to ensure all proper equipment has been checked by the anesthesia provider before its use. Mehta et al. (2021) state that misconnections of the breathing circuit are among the most common preventable issues that lead to patient injury. Furthermore, anesthesia gas delivery equipment constitutes 20% of reported events related to critical incidents (Mehta et al., 2021). Such events included ventilator problems (17.9%), vaporizer problems (5.1%), leaks in the circuit (9.6%), and gas supply issues (1.9%). These are all scenarios that can be simulated in a safe, positive environment. Light anesthesia, which can result in patient injury and recall, occurs in up to 71% of vaporizer malfunction (Mehta et al., 2021). These events were often due to user error resulting from unfamiliarity with equipment or memory lapse (Mehta et al., 2021).

Most anesthesia machine malfunctions are related to user error, therefore establishing a fundamental understanding of how this equipment works is vital to patient safety. SRNAs must develop the ability to recognize and address anesthesia machine failure within the intraoperative period. This education can be provided in a safe, controlled environment with the use of high-fidelity simulation scenarios. It is possible that students who volunteer to participate in simulation scenarios may be better prepared to prevent, recognize, and intervene in anesthesia machine failures sooner than those who do not, thus reducing the risk of harm to the patient.

Problem Statement

There is an inconsistency between professors' expectations and course syllabi regarding simulation hours. While there is some evidence that simulation prepares students for clinical experience, there is no consistent recommendation for open lab hours. The skills students learn regarding machine checks and failure solutions directly affect patient safety. Considering the significance of anesthesia machine malfunctions, it is essential that students be as prepared as possible to trouble shoot issues while maintaining patient safety in the operating room. Students who attend simulation more often may establish a more robust understanding of the anesthesia machine components and respond to unpredictable machine equipment failures quicker. In order to address this, a quality improvement project was performed to assess how voluntary, additional simulation scenarios affect perceived preparedness and technical skills in first year Marian University SRNAs.

Needs Assessment & Gap Analysis

Currently, Marian University SRNAs begin simulation courses in their first year, the semester prior to beginning clinical experiences. While they have a structured syllabi with a course calendar, they do not have a recommended number of practice hours. As is, students are expected to attend lab for one hour each week to learn a pre-determined skill. They are put through "test-outs" to assess their knowledge regarding that skill on a later date, usually a week to a month after their initial learning experience. During this time, they do not revisit that skill during formal lab hours. Additional simulation times are offered to become more familiar with the equipment throughout their first year. These extra hours are voluntary and are left open to students to participate at their discretion.

Although DNAP staff encourage students to take advantage and utilize these open hours for more practice throughout their first year, current student participation is low. Discussions with DNAP staff revealed a general agreement that first-year anesthesia students should attend simulation lab more frequently to foster and solidify skills learned. In order to ensure student participation, Marian University needs to specify its simulation expectations, including open lab hours, within its syllabi. Prior to including additional requirements, however, data needs to be presented to validate the effectiveness of additional practice hours. This project has examined how additional simulation scenarios affect SRNAs' cognitive and perceived progress towards being prepared for clinical experiences.

Aims & Objectives

The first aim of this project was to assess the effect of additional simulation hours on SRNAs' perceived preparedness and self-confidence during anesthesia machine malfunction scenarios. The second aim of this project was to determine if additional simulation experiences improve SRNAs' technical skills by their ability to identify and resolve common anesthesia machine malfunctions. The purpose of this project was to provide support for participation in supplementary simulation time by demonstrating how it impacts SRNAs' readiness to both prevent and address common anesthesia machine malfunctions in a clinical setting. These aims were approached by addressing the following objectives:

1. First year SRNAs will complete voluntary, additional simulation hours to practice anesthesia machine checks and machine failure scenarios prior to beginning clinical experiences.
2. SRNAs will perform a self-evaluation of their perceived preparedness and self-confidence prior to attending additional simulation hours.
3. SRNAs' baseline understanding of anesthesia machine malfunctions will be assessed by completion of a cognitive-based pre-test prior to attending additional simulation hours.
4. Volunteer First year SRNAs will attend a simulation workshop where they will work to address common anesthesia machine malfunctions. First year SRNAs will work with Junior SRNAs to develop comfort and self-confidence in solving simulated anesthesia cases.
5. SRNAs will participate in debriefing sessions immediately following each voluntary experience to document and reflect upon skills, knowledge, and confidence improvements.

6. After completing additional simulation hours, SRNAs will report higher levels of self-confidence in addressing machine failures.
7. After completing additional simulation hours, SRNAs will score higher on a cognitive based assessment.

Theoretical Framework

The conceptual framework that most naturally aligns with this DNP project is Khalili's "Clinical Simulation Practise Framework: A knowledge to action strategy in health profession education." This framework theorizes that simulation learning will help improve learners' competence, confidence, and collaboration in the clinical setting (Khalili, 2015). It was used to establish and implement stimulation experiences for first year SRNAs. The theoretical framework clearly defines three components to make a simulation effective. First, simulations must be "safe, positive, reflective, and fun" in order to provide students with an environment that fosters education (Khalili, 2015). The next is a realistic, but challenging scenario that will push students to apply their knowledge and provide life-like situations. Lastly, all effective simulations should be interprofessional and interactive patient-centered scenarios (Khalili, 2015).

Safe, Positive, Reflective and Fun Simulated Learning Environment

This study utilized upperclassman-led simulation, which allowed first year students to participate in a safe and positive environment without fear of failing in front of faculty or clinical instructors. In order to further establish a safe, reflective, and fun learning environment, a nonjudgmental and non-threatening approach was needed. This was facilitated by providing learners with the educators' expectations for the simulation while still maintaining the integrity of the simulation experience. Learners were instructed that perfection was not expected, but an emphasis was placed on respectful participation and critical thinking. As soon as the simulation began, educators were no longer available for questions. However, debriefing and evaluation were conducted post simulation using a nonjudgmental, open-table approach. Participants were encouraged to share their experience and perspective of the scenarios provided. They were guided through a discussion of their interventions and rationales during the simulation. Following the debriefing, the educators revealed additional teaching points for future applications. The participants were encouraged to reflect on their experience before the debriefing was concluded.

Challenging, but Realistic, and Integrated Simulated Scenarios

This element centers on the integration of realism into the simulation. In order to achieve this goal, high-fidelity simulation was applied. High-fidelity simulation involves the incorporation of a manikin, or a high-fidelity human patient simulator (HPS), that has the ability to mimic or closely resemble human physiology. The HPS used replicated sounds (heart rate tones, breathing, talking), movement (pulsation, blinking), and visual waveforms on monitors. These were manipulated based on condition changes, treatment, and equipment (pulse oximetry, EKG, capnography, tidal volumes). Implementation of this high-fidelity simulation allowed the participants to benefit from the most realistic environment possible. Various procedures were performed on the HPS including intubation and bag-mask ventilation. Specific scenarios were chosen from anesthesia machine failure case studies to ensure that they remained realistic. Because the learning experiences took place in a closed and controlled environment, distractions and outside variables were able to be limited. These factors helped enable students to fully engage in their realistic learning environment.

Interactive, Inclusive, Interprofessional Patient- Centered Simulated Practice

While this project did not involve professions other than nurse anesthetists, it included facility mentors and students from two different cohorts. Furthermore, communication and collaboration with team members was necessary in order complete the simulations. This satisfied the interprofessional requirement of Khalili's framework. In order to ensure the scenarios were patient-centered, machine failure scenarios were implemented that would impact the HPS physiology. Participants utilized hemodynamic monitors and physical assessment to evaluate overall patient status. This gave the SRNAs an opportunity to relate machine failures to patient care and safety in real time. Critical thinking and problem solving were also necessary in providing patient-centered care. Despite the complexity of the machine failure scenarios, the participants were primarily tested on prioritization of patient-centered care.

SWOT Analysis

Addressing the advantages of additional simulation time benefits a number of parties. Key stakeholders included simulation professors, directors, and SRNAs currently or soon to be enrolled in simulation courses. Marian University's CRNA program are also stakeholders since course and program curriculum can be adapted to include required additional hours if proven to be beneficial. Strengths of the project included using a convenience sample of volunteer students and required no financial investment. Student were not denied teaching or standard learning, leaving room for no present ethical concerns. Lastly, the project required one to two hours from its volunteers. The project also provided participants a helpful review of course material prior to the course final. These factors made the project appealing to potential volunteers. A detailed SWOT analysis chart can be seen in Appendix C.

Review of the Literature

Literature Search Methodology

A literature search was conducted on December 27, 2021, using PubMed, Ovid/Medline, Ebscohost/Medline, and CINAHL databases. Initially, three separate searches were conducted. The first keywords searched was BOOLEAN phrase anesthesiology or anesthesia or equipment failure. This resulted with a total article count of 106,460. A following separate search was conducted using BOOLEAN phrase high fidelity simulation training or patient simulation or simulation training. This resulted with a total article count of 10,861. A third separate search was conducted using keyword anesthesia machine malfunction. This resulted with a total article count of 946,784. The BOOLEAN phrase was adapted to combine these separate searches such as equipment failure AND simulation training AND anesthesia machine malfunction. A filter was also added to limit literature article results to include only English articles with studies conducted using humans. This search yielded 30 articles. Duplicate articles found between databases were identified and removed from the literature search. Inclusion criteria included primary sources and peer-reviewed studies. Exclusion criteria included secondary sources and equipment failures unrelated to anesthesia. After applying inclusion and exclusion criteria, 12 articles remained and were used for the review of literature.

To find articles based on simulation within the BSN world, another search was conducted. Multiple databases were searched in December and January of 2022 to find articles about how simulations affect self-confidence in BSN students. Key words included *simulation*, *nursing students*, and *self-confidence*. Because self-confidence and self-efficacy are often used interchangeably, *self-efficacy* was also included as a key word. Eric was searched using the Boolean phrase *nurs* AND simulat* AND self-efficacy OR confidence*. From this, 29 articles were found. Next, PubMed was utilized with filters set as publication date within five years or less, clinical trials, and randomized control trials. The Boolean phrase *(nurs* AND student) AND simulat* AND confidence OR self-efficacy* was used to find 63 articles. Additionally, two more articles were found through mining sources, making the grand total 94 articles. Of these, five were duplicates.

The remaining articles were screened using exclusion and inclusion criteria. Sixty-one articles were excluded immediately based on abstract and/or title. Next, 28 articles were read. Inclusion criteria included: focus on the keywords, main subject regarding BSN simulation experiences with specific topics, pre and post-test evaluations over skills improvement and confidence, and pieces that juxtaposed simulations to traditional learning methods. Exclusion criteria included: virtual simulations, video supplements, emphasis on pre- or post-briefing, and comparison of as the main focus. Experiments based in hospitals and articles focused on work-place environments were also excluded. These criteria narrowed the 28 articles down to 9 articles, which were included in this review.

Synthesis of Literature Review

Much of the literature supports incorporating simulation-based learning as an adjunct to standard training in order to better prepare clinicians for anesthesia machine failures. Morgan et al. (2003) states that high fidelity patient simulation offers an ideal venue in which students can practice and incorporate classroom knowledge of critical events without jeopardizing patient safety. Errors and faults that result in this setting can be simulated, which allows the anesthesia student to have exposure to these encounters in a safe and controlled setting. Since anesthesia equipment malfunctions are primarily due to human error (Dalley et al., 2004), additional simulation participation can assist in lowering this occurrence by creating better clinically prepared anesthetists. Through simulation, educators are able to indirectly assess student's clinical performances and determine whether the educational objectives taught in the curriculum are matched by the performance in the OR setting (Morgan et al., 2003). Anesthesia simulation-based training scenarios also provide educators a chance to see if their curriculum teaching is effective as a whole. By evaluating an entire cohort, educators would be able to identify common problems and misunderstandings. This aids educators in identifying fundamental educational problems that would require revisitation on the topic (Weller et al., 2007).

In anesthesia, patient safety depends on the interaction between the anesthetist and the equipment (Dalley et al., 2004). Foreignness to anesthesia equipment has been identified as a major factor in the development of adverse events (Dalley et al., 2004). Thus, unfamiliarity of differences in various machines may potentially contribute to the development of anesthesia malfunctions. Because set up and safety checks can vary from machine to machine, if anesthesia clinicians are not accustomed with individual systems, errors, machine malfunctions, and patient safety events may occur. Anesthesia machines differ in breathing circuit design, ventilator control, fresh gas delivery; all of which directly contribute to 14-30% of all intraoperative problems that develop (Dalley et al., 2004). In order to avoid patient harm, it is critical for the anesthesia clinician to be able to quickly identify and resolve these equipment failures in a timely fashion.

Increased simulation training can facilitate improvements in troubleshooting unpredictable scenarios. Weller et al. (2007) states that technical malfunctions are rare in anesthesia but can result in major morbidity and possibly death when they do occur. Continual exposure in the simulation setting can become a primary preventative measure that could be exercised to reduce malfunction errors in the clinical setting. Larson et al. (2007) states that human error and insufficient preanesthetic machine checks are a recurring theme. Students who volunteer in simulation more often may establish an in-depth preanesthetic machine check routine quicker, recognize machine errors sooner, and deliver faster intervention, thus reducing the risk of patient harm. Additional participation and practice in simulation scenarios prior to integration into the clinical setting may aid in prevention or faster resolve of these common malfunctions.

There are often many measures that can be taken to resolve an anesthesia machine equipment malfunction or failure; some approaches are more effective than others. Weller et al. (2007) conducted a simulation study that revealed concerning results. In the simulated clinical scenario case study, anesthetists were presented with a motor vehicle accident victim that required a minimum of 70% inspired oxygen concentration. At some point during the simulation, the oxygen pipeline supply failed. All the anesthetists were able to continue managing ventilatory support. In order to maintain oxygenation, all the anesthetists turned on their backup cylinders when the pipeline failed. Only 30% of the anesthetists had recognized that the backup oxygen cylinder was empty pre-operatively. Upon recognition of the empty back up cylinder, all anesthetists quickly requested a full cylinder to resolve the issue. All the anesthetists in this simulation-based scenario would have saved the patient's life. However, this scenario highlights the deficiencies of an inadequate preoperative machine check (Weller et al., 2007).

In a similar study to evaluate management of a simulated oxygen pipeline failure, high-fidelity simulation was used to teach and assess clinical skills of anesthesia students. This study found that management of an oxygen pipeline failure was poorly understood among the participants based on their performance. Many students primarily and solely relied on the use of the Ambu bag as the main source to ventilate and oxygenate the patient, disregarding the available reserve tank on the back of the anesthesia machine (Lorraway et al., 2006). This showed evaluators that further education on the anesthesia equipment was necessary.

Another study was conducted regarding oxygen pipeline crossover. The researchers reversed the connections between the oxygen and nitrous oxide pipelines and reviewed the response of the anesthesia subjects. Many of the anesthesia clinicians recognized an issue with the oxygen source, however 60% resorted to using the axillary flowmeter as a backup source of oxygen (Mudumbai et al., 2010). The auxiliary flowmeter receives its oxygen from the pipeline, which in this scenario is administering nitrous oxide due to the crossover.

These studies emphasize the importance of a thorough pre-operative machine check prior to the use of the anesthesia machine. Components such as an empty backup cylinder or gas crossover may have been recognized prior to the initiation of patient care and delivery of anesthesia to the patient. These studies further advocate toward the benefits of additional simulation training. More exposure to these anesthesia machines in a simulation setting may assist with establishing a thorough and appropriately detailed machine pre-check, thus preventing the previously described scenarios. Weller et al. (2007) states that a high-fidelity patient simulation offers anesthetists the chance to test the students' response to many critical equipment related events and assist in identifying common management errors.

Simulation has proven to be useful in other settings outside the medical arena. It is especially useful in aviation to evaluate equipment and technological failure as well as explore human-machine interaction (Mudumbai et al., 2010). Simulation enables the ability to recreate rare situations that require prompt attention, rapid judgement, and quick decision making, producing similar high stakes conditions that occur in real life scenarios. Simulation has also been a valuable resource during the current COVID19 pandemic. The record-breaking spread and the unprecedented nature of this virus has made healthcare providers anxious and fearful to say the least. The virus has forced many clinicians to adapt to unfamiliar departments due to shortages and high demand. At times, clinicians may not have the baseline foundational knowledge to work on such units, which in turn could risk harm to the patient. Simulation has been able to assist in alleviating these concerns. It offers a setting where clinicians can develop new skills in a controlled safe environment while simultaneously increasing confidence towards approaching real-world crisis (Ekert et al., 2020). Simulation has become a necessary source for training during these unpredictable times. In summary, the advantage of simulation implementation throughout every field is its ability to allow participants to be able to interact with the equipment by exploring its function. Participants and viewers are able to examine management strategies through replication of a scenario in a controlled environment where there is no risk of harm to another being (Mudumbai et al., 2010).

Mudumbai et al. (2010) found that participants' lack of knowledge of the anesthesia machine coupled with incidental shortcomings of equipment designs is a recipe for potentially lethal outcomes. Anesthesia machine and equipment malfunctions are often unpredictable. Therefore, diligence of the anesthetist must be taken to ensure all proper equipment is available, has been checked, and intact before it is ready to use. Potential ramifications of a novice anesthesia provider include patient awareness. Light anesthesia is one of the most common problems resulting from vaporizer delivery issues. The development of light anesthesia may be due to user error related to lack of familiarity with equipment. The majority of equipment failures develop from user error. Early exposure in the simulation setting may prove advantageous in further lowering these incidences in the clinical setting.

Despite having a reasonably low incidence, anesthesia machine malfunction can lead to severe injury. Mudumbai et al. (2010) reveals that the American Society of Anesthesiologists Closed Claims Analysis Database found that respiratory and equipment events constitute a significant cause of malpractice claims. The majority of anesthesia delivery equipment claims, although infrequent, were a result of provider error. One study's results displayed that anesthesia practitioners were not able to clearly identify preset machine faults (Larson et al., 2007). Additional provider training that outlines appropriate preanesthetic machine equipment and check-out procedures may be able to assist in correcting this issue. This education may be best provided in a high-fidelity simulation-based setting where anesthesia students can receive appropriate training in a similar environment where assessment and evaluation of their performance can be critiqued. Debriefing is a critical component of simulation training. It provides participants the opportunity to discuss rationales for behavior and decisions practiced during the simulation (Khalili, 2015). Increased time spent in simulation may also promote student cognitive retention for earlier detection and resolution of anesthetic errors that occur in the clinical setting.

As previously mentioned, a critical component of high-fidelity simulation training is the post simulation debriefing. This is the time where the participants are afforded an opportunity to discuss their performance, rationales, and their overall simulation experience with the evaluators. Evaluators are also able to provide feedback and critique the participant's simulation performance during this time. Edwards et al. (2018) state that debriefing is where 80% of the learning occurs and thus has been deemed the most important phase of simulation. During this phase, participants are able to identify their weaknesses and strengths. The general goal of debriefing is for students to gain more insight into their practice, ensure educational development and emotional support, and become dynamic participants in their learning (Edwards et al., 2018). All this is achieved under the safety net of a calm, non-judgmental, and controlled environment where questions can be explored, and wrong answers are not penalized, but rather corrected with explanation through discussion. The result of these outcomes achieved by the implementation of simulation is a more robust student; one that is more confident and competent in performing professional practice in real life settings (Khalili, 2015).

In order to understand the impact high-fidelity simulation can contribute, it would be pertinent to review previous studies and outcomes that compare participants that attend simulation versus those that do not. A study was conducted to compare nurses who underwent high-fidelity simulation over the use of Continuous Renal Replacement Therapy (CRRT) versus nurses that did not. Patients with acute kidney injury on CRRT were found to not be receiving the full benefits of CRRT due to frequent unplanned interruptions in its use. There were many reasons for these unplanned interruptions, some of which included filter clotting or clogging, decreased flow rates, catheter dysfunction, or coagulation. Most of these issues arose due to ineffective resolution of alarms that led to decreased blood flows (Lemarie et al., 2019). All nurses had previous simulation training on the use of the CRRT machine. However, the study hypothesized that additional simulation training may be able to minimize the number of unplanned interruptions that occurred with patients on CRRT which would increase its overall usefulness. An experimental research design was used, and nurses were randomly separated into an experimental group (nurses that attended the high-fidelity simulation training) and control group (nurses that did not attend high-fidelity simulation training for CRRT). They assessed outcomes using pre and post intervention knowledge tests and simulation evaluation. The results of the study found that nurses of the experimental group scored better results on their post intervention knowledge test and required less calls for assistance during the simulation evaluation when compared to the control group. The experimental group also felt more confident and less stressed in starting and troubleshooting the CRRT machine (Lemarie et al., 2019). The outcomes of this study further advocate the many benefits behind the execution of additional simulation training.

It is pertinent to take into consideration that some facilities utilize anesthesia technicians. Anesthesia technicians are typically tasked with restocking the medication and equipment carts, in addition to performing the daily pre-anesthesia check as well safety checks between each case. Many facilities advocate that their role promotes time efficiency and benefits the anesthesia provider by allowing them additional time to complete a more robust preoperative assessment of their next patient. However, one study found that the time saved by allowing technicians to complete the pre anesthesia machine check may be impacting anesthesia providers' ability to perform a proper machine check. Armstrong-Brown et al. (2000) study looked at the ability for participants to detect machine faults based on their knowledge of the equipment. The study found that participants rate of fault detection was low. Armstrong-Brown et al. (2000) found that participants understood the function of the machine but struggled to apply the understanding to practical clinical skill. It is the legal responsibility of the anesthesia provider to assess and determine appropriate function machine equipment regardless of whether or not the technician has already completed this task. With that in mind, it is critical that all components of the machine checklist are checked and verified in order to assure proper function prior to use on patients. Incomplete or partial checks may hinder the ability for one to identify machine faults or failures. Armstrong-Brown et al. (2000) states that if pre-use machine checks are truly a patient safety concern, then they should not be optional.

How can the validity of simulations' effectiveness be evaluated? One study looked to review how truly effective and beneficial the added experience of high-fidelity simulation truly is based on specific grading criteria measures. Using two different grading forms, Schwid et al. (2002) reviewed footage of subjects taking part in a high-fidelity simulation to and used two grading forms to score their performance. Construct-related validity (determines whether simulation evaluation is a legitimate indicator of performance) and criterion-related validity (compares results of simulation to other measures of participant performance) were supported (Schwid et al., 2002). Participants rated the simulation as realistic which supports construct-related validity as a simulator evaluation tool. The correlation between the simulator scores and department evaluations supported criterion-related validity (Schwid et al., 2002). The progression of simulator scores from novice to 4th year anesthesia resident participants further supported the reliability and validity of simulation.

Another way to evaluate the effectiveness of simulation is to look not ahead into the professional world, but rather into undergraduate nursing programs. Although simulation-based research is severely lacking within the world of doctorate nursing programs, slightly more literature is available at the bachelors' level. A majority of these studies are either experimental or quasi-experimental and involve convenience samples of students within the host university. By examining students' perceived preparedness for clinicals and self-confidence levels pre and post-intervention, these studies evaluate the effectiveness of simulation experiences compared to traditional learning experiences (such as lectures or reading-based material). Although helpful, not all of the data is straight forward.

Saied (2017) used a quasi-mixed methods study to examine the effects of pediatric simulations compared to traditional learning. His results showed that although simulation participants had significantly increased knowledge scores, their self-efficacy scores were significantly lower than their counterparts' scores (Saied, 2017). A randomized control trial showed a slight, but not significant improvement in students' self-confidence following simulation when compared to traditional learning (Alamrani et al., 2018). Kahraman et al. (2019) performed a quasi-experimental study in which the experimental group participated in pediatric emergency simulations. They, however, also failed to demonstrate a significant improvement in simulation participants' self-efficacy but did show that students had better attitudes towards pediatric emergencies going forward. A recent randomized control study showed that additional simulation experiences had no effect on students' confidence levels (Svllingen et al., 2021). This study compared a control group that participated in a single round of simulations to an experimental group that participated in double simulations over three years.

Other groups, such as Basak et al. (2019) however, found much more encouraging results. An experimental, randomized control trial showed that simulations on patient education significantly increased students' self-confidence and critical thinking scores when compared to traditional learning methods (Basak et al., 2019). Li et al. (2019) also showed that self-efficacy was not the only significantly increased score: empathy and communication were also increased in simulation participants when compared to non-simulation-based learning. In fact, another quasi-experimental study showed that nursing students who participated in obstetrics simulations had better overall performances and significantly increased self-confidence than their counterparts that benefitted solely from traditional learning (Gray & Cavner, 2017). Tamaki et al. (2019) demonstrated significantly improved self-confidence, skill-performance, and knowledge scores following an end-of-life care simulation when compared to traditional learning. Furthermore, simulations may continue to build confidence over periods of time. One correlational study showed that maternity exam simulations significantly improved students' self-confidence not only at an initial post-test, but saw another significant improvement following another questionnaire two days later (Germain et al., 2018).

The overwhelming support for further anesthesia machine training demands a change in SRNAs' education. Simulations have been shown to improve the knowledge and confidence of anesthetists in the professional world. Although most evidence supports the use of simulations for undergraduate nursing students, it is not an overwhelming consensus. Therefore, there is a gap in the literature that cannot be filled based on the conclusions of current literature. The lack of support for simulations within the DNP world, however, needs to be addressed. In particularly, the effects of voluntary simulation experiences and simulation experiences regarding anesthesia machine malfunctions within SRNAs.

Project Design and Methods

Project Site and Population

A convenience sample of SRNAs was selected to participate in this one-group, pretest posttest quasi-experimental design. The cohort consisted of 32 first year SRNAs attending the Marian University School of Anesthesia. SRNAs were not initially assigned to a control or experimental group. Students unwittingly self-selected their group based on their decision to participate in additional simulations offered by the researchers of this study. The simulation workshop took place in the Evans Center second floor simulation laboratory. The lab provided a familiar, high-fidelity learning environment without added cost to the participants or researcher. The simulation site was also a convenient location that allowed for students to participate with minimal interruption in their daily schedule.

Measurement Instruments

The pretest and posttest used in the study were identical. They consisted of 10 questions that assessed baseline understanding, comprehension, judgment, and application of the anesthesia machine and equipment information received by the professor. They also included a modified version of the validated Student Satisfaction and Self-Confidence in Learning tool, borrowed from the National League for Nursing. The tests were distributed as a hard copy after the completion of a regularly scheduled class. Students were asked to work independently to complete the test and hand it back into the researcher prior to leaving. The correct answers to the first portion were not revealed until after the study was complete in order avoid alterations to data. The questionnaire is shown in Appendix E.

Data Collection Procedure

As required by the anesthesia simulation lab curriculum set forth by the simulation professor Dr. Monteiro, all 32 students attended an initial introductory session of the anesthesia machine and its major components. This was be led by faculty. Some weeks later, the architects of this study administered the pre-test that addressed performance and confidence.

After the entire cohort completed the pretest, students were offered the opportunity to attend additional simulation practice led by the researchers. The topic of education focused on anesthesia machine equipment and common malfunctions experienced in the clinical setting. The simulation experiences, which consisted of two scenarios each, lasted one hour. During the first week, the scenarios were available for participation from 0800-1600 for two consecutive days. The same schedule was repeated with two new scenarios during the second week. This resulted with a total of four available scenarios and 32 available time slots.

The first scenario offered was a general anesthetic during which an oxygen pipeline failure occurred. Pipeline pressure failure was simulated during the maintenance phase of a general anesthetic. Participants were responsible for identifying the malfunction and using problem solving skills to ensure patient safety for the duration of the anesthetic. The second simulation, which featured an expired carbon dioxide absorber, presented with steadily climbing inspired and expired carbon dioxide. Once students identified the expired absorber, and increased fresh gas flows in order to maintain patient safety, the rest of the case proceeded uneventfully. Students who participated in the third scenario were presented with a circuit leak. The source of the leak was located at the y-piece, but students were encouraged to trace the length of the circuit during their debriefing. The final simulation required students to work through a complete power failure of the anesthetic machine. Students were expected to maintain patient safety by providing manual ventilation and switching to a total intravenous anesthetic. They were also expected to communicate all machine malfunctions with the operating team, anesthesia team, and engineering department.

Participation was not limited to a set number of sessions. Students were grouped together based on open lab sign ups, in groups of two to six. A debriefing was conducted after each simulation session to discuss and review any questions the participants may have had. After the sessions were complete, the entire cohort, regardless of simulation participation, took the post-test assessment that addressed performance and confidence. After the tests were collected, the correct answers and rationales were made available via e-mail.

Ethical Considerations

In order to maintain the integrity of the study, in addition to providing protection of the participants, data and attendance was tracked using the last four numbers of each students'

Marian ID number to maintain anonymity. This helped minimize the risk of biases that may result unintentionally. The pre and post simulation examination results were not released outside of the researcher's possession. The pre and post tests were collected immediately upon completion and answers were not released until after the entire study was completed.

Data Analysis and Results

After implementation of the study, the information was documented on paper then coded into a statistical computing program called R. Each participant was represented by the last four numbers of their student ID number to maintain confidentiality. The frequency of participation in simulation education was also recorded and entered into the software. Other quantitative variables collected from the study were also plugged into the program. These variables included age, gender, ethnicity, marital status, years of critical care nursing experience, average weekly study hours, pretest and post test scores, and their average lab participation hours.

Once all the data was inputted, a multiple regression was initially used to analyze the main predictor variable, testing the impact that attending the provided information sessions had on the post-test scores of the participants which is the outcome variable. The attendance was broken into two categories: students that attended at least once and students that attended at least twice. Both gave back very high p-values (p=0.5615 and p=0.9491, respectively), indicating that attending sessions did not have a statistically significant impact.

Table 1: Multiple Regression Results for Post-Test Score

		Confidence Intervals		
	Estimate	2.5 %	97.5 %	Pr(>|t|)
Pre_Score	0.28	-0.16	0.73	0.20
Attend_1	0.40	-1.03	1.82	0.56
Attend_2	0.07	-2.13	2.27	0.95
Age_Group	-0.18	-1.12	0.75	0.68
Gender	-0.06	-1.33	1.22	0.92
Ethnicity	-0.18	-0.78	0.41	0.53
Marital_Status	-0.03	-1.78	1.72	0.98
ICU_Exp	0.36	-0.77	1.48	0.51
Study_Hours	0.21	-0.31	0.72	0.40
Lab_Attend	-0.16	-1.08	0.76	0.72
Conf_1	-1.18	-2.38	0.02	0.05
Conf_2	1.14	-0.26	2.54	0.10

Multiple regression was also used to test the other predictor variables against the post test scores, including the pre-test score, self-reported confidence levels of the students during both pre-test and post-test, ICU experience, average hours spent studying in each week and average weekly lab attendance. Other demographic variables were also tested including age range, gender, ethnicity, and marital status.

All predictor variable returned high p-values at the 95% significance level, except for the student's confidence on the pre-test, which gave back a nearly significant p-value of p=0.0533.

Table 2: Multiple Regression Results for Confidence on Post-Test

		Confidence Intervals		
	Estimate	2.5 %	97.5 %	Pr(>|t|)
Pre_Score	0.09	-0.07	0.25	0.24
Post_Score	0.15	-0.03	0.33	0.10
Attend_1	0.09	-0.43	0.60	0.72
Attend_2	0.05	-0.74	0.84	0.90
Age_Group	0.11	-0.22	0.44	0.48
Gender	-0.20	-0.64	0.25	0.36
Ethnicity	0.10	-0.11	0.31	0.34
Marital_Status	-0.30	-0.90	0.31	0.31
ICU_Exp	-0.02	-0.43	0.39	0.90
Study_Hours	0.00	-0.19	0.19	0.99
Lab_Attend	-0.11	-0.43	0.22	0.49
Conf_1	0.69	0.38	1.00	0.00

Multiple regression was also used to calculate the impact of other various predictor variables on the confidence of students when taking their post-test. The main variable of interest was the students' attendance to the offered session, which was broken into the same two categories as above: students that attended at least once and students that attended at least twice. When analyzed, both returned high p-values (p=0.7227 and p=0.8981, respectively), indicating that attending the information sessions did not have a statistically significant impact on the confidence of the student while taking the post-test.

The same analysis was completed to test the other predictor variables, including the pre-test and post-test scores, self-reported confidence levels of the students during the pre-test, ICU experience, average hours spent studying in each week and average weekly lab attendance. Other demographic variables were also tested including age range, gender, ethnicity, and marital status.

Most of the predictors returned high p-values at the 95% significance level, however, there was a statistically significant result with the self-reported confidence levels of students during the pre-test.

Discussion

There were a variety of limitations that held back this study. One weakness of the project was the necessity to plan it around a pre-existing course syllabus. This limited the available time in which the project was able to be implemented. The project was also dependent entirely upon voluntary student participation, a weakness that ultimately limited sample sizes. An unforeseen weakness was the business of the simulation lab. Other junior level SRNAs were available for teaching during the weeks of this study. This pulled participants from the scenarios designated for the project. Other issues that arose included lag and sometimes inoperability with the control unit's communication with both the high-fidelity simulation mannequin and the anesthesia machine. Perhaps one of the biggest opportunities that benefited this project was the overall availability and proximity of the simulation lab. It is frequently open to students for additional practice hours and can be made available during other times by request. Because all first year SRNAs are required to enroll in simulation courses, they are also encouraged by their professors (and COA) to participate in additional hours.

This study showed that attending open lab sessions any number of times did not increase the performance of the students, nor did it have an impact on student's overall confidence. Despite the aforementioned limitations, participants were still able to effectively discuss resolution for the given anesthesia clinical scenario. Allowing students to effectively discuss the case as a group seemed to aid in a swifter response in the simulation. Open discussion with the researchers after the simulation also seemed to increase further confidence. This information was passed on to the researchers by the participants during the post simulation debriefing session.

This analysis addressed two aspects of attendance: first comparing participants that did attend open lab sessions with those that did not (Attend_1), and the second whether frequent session attendance improved overall performance (Attend_2). Both of these concepts revealed no significant results. However, in regard to confidence, there was significance found. If a student was confident while taking the pre-test, there was a greater likelihood that the student would be confident while taking the post-test as well.

Although few significant effects were identified in the present analysis, it is likely due to the fact that the present sample size is only 28. A priori power analysis with 12 factors was completed using an estimated effect size of 0.02. This power analysis was chosen due to Cohen's 1988 guidelines (Cohen, 1988), which recommends using an f^2 value of 0.02 for small effect sizes. Based off the power analysis it was suggested that a sample size of 877 is needed to properly power the present study. Increasing the sample size to appropriately power this study could elucidate effects that were not observed in the present, underpowered analysis. It would be pertinent for future research into this hypothesis to use an appropriate sample size with equipment that has been appropriately tested and deemed operable. This could potentially reveal a more robust and definitive outcome between the correlation of frequency in open lab simulation attendance and future performance for identifying and addressing anesthetic malfunctions.

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Appendix A

Theoretical Framework

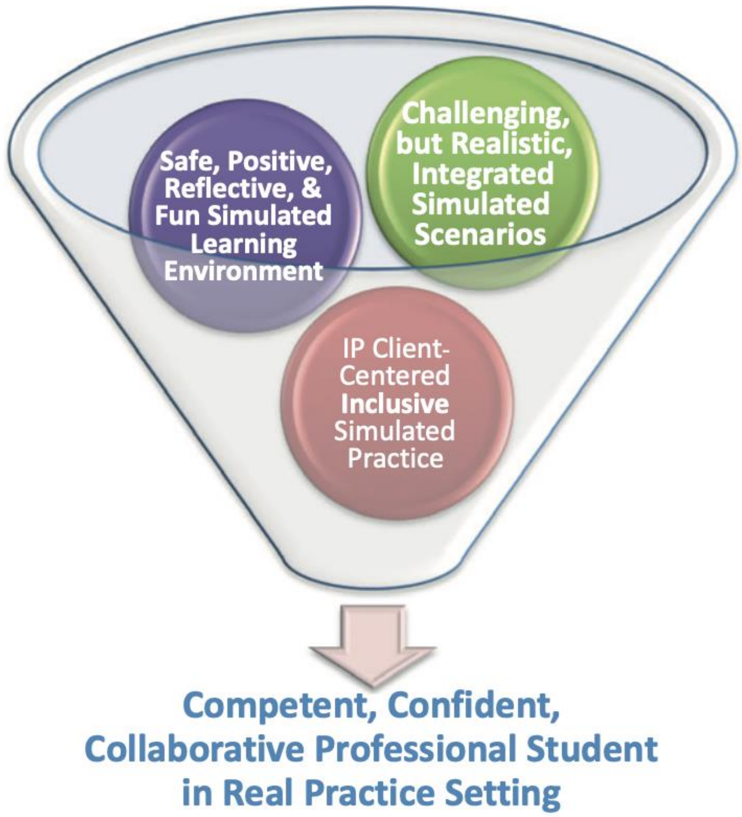
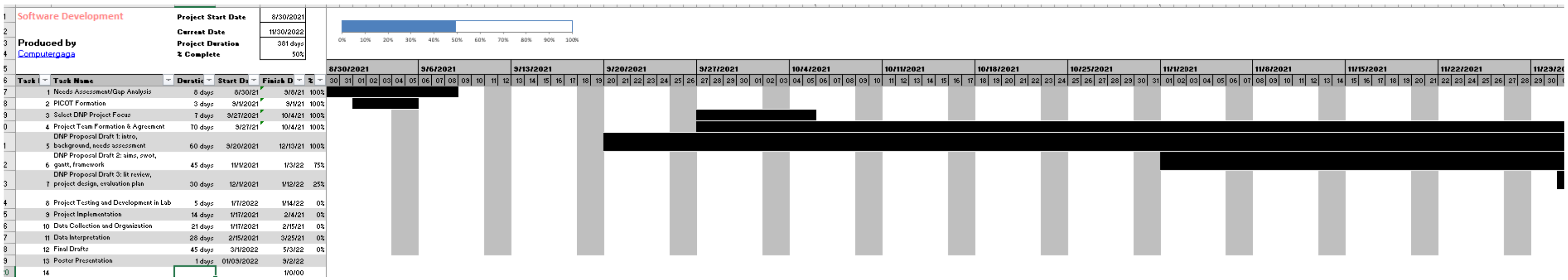
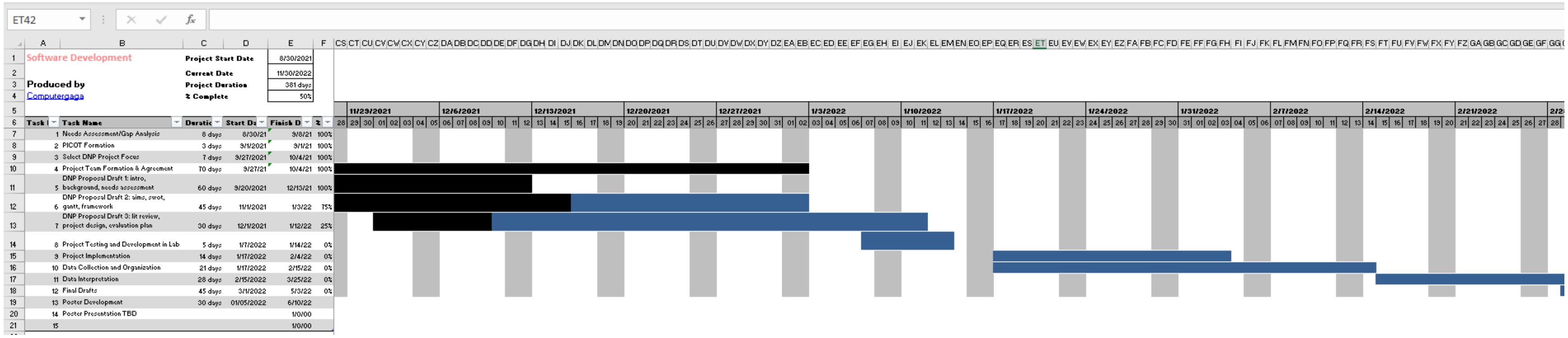


Figure 1. Depicts a visual representation of Khalili's "Clinical Simulation Practise Framework: A knowledge to action strategy in health profession education." (Khalili, 2015).

Appendix B

GANTT Chart



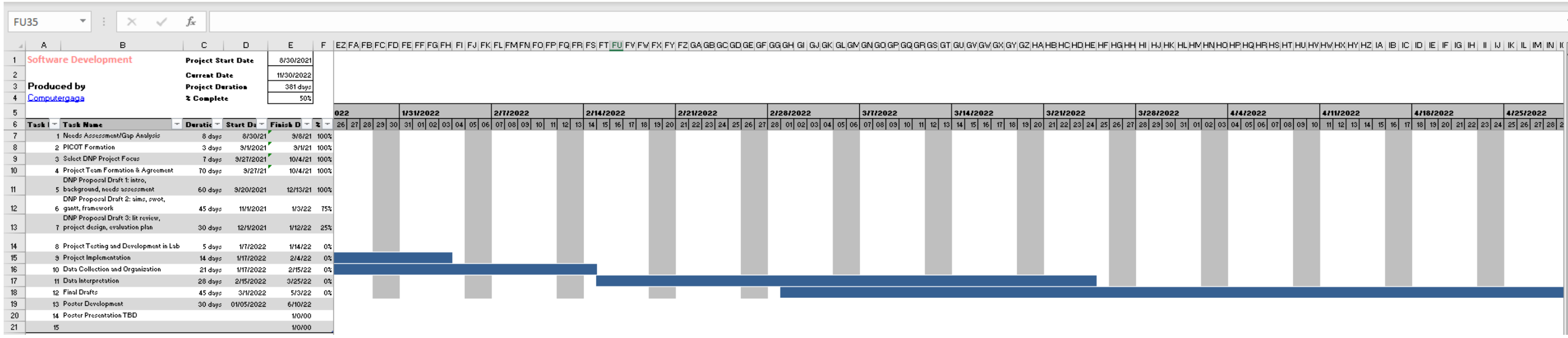


Software Development

Produced by [Computergaga]

Project Start Date	8/30/2021
Current Date	11/30/2022
Project Duration	381 days
% Complete	50%

Task ID	Task Name	Duration	Start Date	Finish Date	%
1	Needs Assessment/Gap Analysis	8 days	8/30/21	9/8/21	100%
2	PICOT Formation	3 days	9/1/2021	9/1/21	100%
3	Select DNP Project Focus	7 days	9/27/2021	10/4/21	100%
4	Project Team Formation & Agreement	70 days	9/27/21	10/4/21	100%
5	DNP Proposal Draft 1: intro, background, needs assessment	60 days	9/20/2021	12/13/21	100%
6	DNP Proposal Draft 2: aims, swot, gantt, framework	45 days	11/1/2021	1/3/22	75%
7	DNP Proposal Draft 3: lit review, project design, evaluation plan	30 days	12/1/2021	1/12/22	25%
8	Project Testing and Development in Lab	5 days	1/7/2022	1/14/22	0%
9	Project Implementation	14 days	1/17/2022	2/4/22	0%
10	Data Collection and Organization	21 days	1/17/2022	2/15/22	0%
11	Data Interpretation	28 days	2/15/2022	3/25/22	0%
12	Final Drafts	45 days	3/1/2022	5/3/22	0%
13	Poster Development	30 days	01/05/2022	6/10/22	
14	Poster Presentation TBD			1/0/00	
15				1/0/00	



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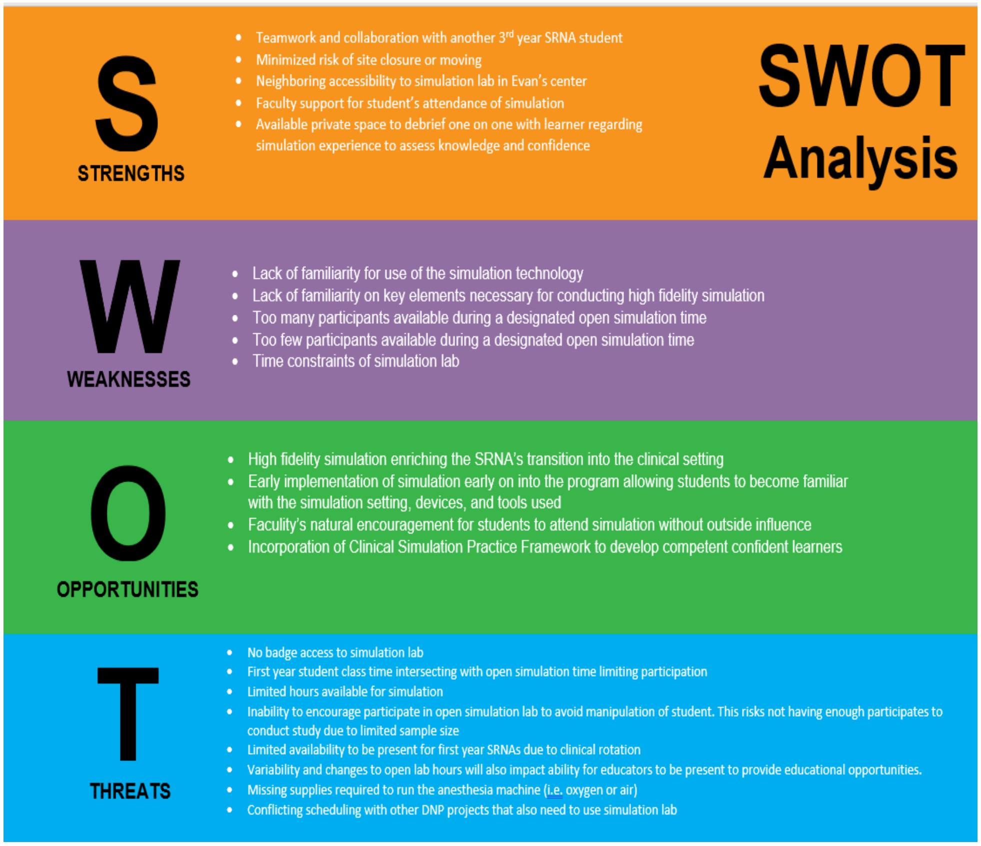
3	Select DNP Project Focus	7 days	9/27/2021	10/4/21	100%
4	Project Team Formation & Agreement	70 days	9/27/21	10/4/21	100%
5	DNP Proposal Draft 1: intro, background, needs assessment	60 days	9/20/2021	12/13/21	100%
6	DNP Proposal Draft 2: aims, swot, gantt, framework	45 days	11/1/2021	1/3/22	75%
7	DNP Proposal Draft 3: lit review, project design, evaluation plan	30 days	12/1/2021	1/12/22	25%
8	Project Testing and Development in Lab	5 days	1/7/2022	1/14/22	0%
9	Project Implementation	14 days	1/17/2022	2/4/22	0%
10	Data Collection and Organization	21 days	1/17/2022	2/15/22	0%
11	Data Interpretation	28 days	2/15/2022	3/25/22	0%
12	Final Drafts	45 days	3/1/2022	5/3/22	0%
13	Poster Development	30 days	01/05/2022	6/10/22	
14	Poster Presentation TBD			1/0/00	
15				1/0/00	

Appendix C

SWOT Analysis



Appendix D

Literature Review Matrix

Reference	Research Design & Level of Evidence	Theoretical/ Concept Framework	Purpose/Aim	Population/Sample n=x	Variables	Instruments/ Data Collection	Results	Implications for Future Research	Implications for Future Practice
Morgan, P.J., Cleave-Hogg, D., & Tarshis, J. (2003). Identification of gaps in the achievement of undergraduate anesthesia educational objectives using high-fidelity patient simulation. *Anesthesia & Analgesia, 97*(6), 1690-1694. https://doi.org/10.1213/01.ANE.0000086893.39567.D0	Case control non experimental study (Level 4)	N/A	To identify key educational gaps in medical students' knowledge using human patient simulation that should be addressed in the anesthesia curriculum	135 students	Defibrillate Manually ventilate with 100% oxygen Note other vital signs Call for defibrillator/crash cart Check lung fields for air entry Give intravenous fluids Have plan if ventilation unsuccessful Verbalize possible diagnosis/plan	Checklist was developed for each scenario	75% of students achieved 11 of 18 identified objectives 50% of subjects did not confirm the blood pressure before institution of treatment for tachycardia 40% of residents did not decrease anesthetic	Inclusion of machine checks or problems as an educational objective	Simulation technology therefore presents educators with the opportunity to assess students' performances using standardized cases and to determine whether the educational objectives set out in the curriculum are being matched by performance in a

					Initiate Basic or Advanced Cardiac Life Support protocols Prepare to intubate Initiate treatment Increase oxygen concentration Repeat laryngoscopy/some different airway maneuver History focusing on cardiovascular or respiratory system Turn off anesthetic Call for help Confirm blood pressure Check endotra				clinical setting

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					cheal tube through cords				
Dalley, P., Robinson, B., Weller, J., & Caldwell, C. (2004). The use of high-fidelity human patient simulation and the introduction of new anesthesia delivery systems. *Anesthesia & Analgesia*, *99*(6), 1737-1741. https://doi.org/10.1213/01.ANE.0000136804.46675.EA	randomized, controlled, prospective trial (Level 2)	N/A	To support the use of simulation with introduction of novel complex anesthetic equipment to improve the ability to manage subsequent critical incidents and provide insight into potential design errors without risk to patient	15 enrolled participants	Tested participant's understanding of the pressure-limiting function Tested the participant's understanding of the FGF control and the ability of the Drager Fabius GS to ventilate the patient with entrained room air	Scenario A: The times from intubation to the recognition of severe bronchospasm and initiation of effective treatment were recorded. Scenario B: Times were recorded from completion of the handover of care to the provision of an adequate FiO2, minute volume, and anesthetic vapor Assessments	No statistically significant differences between groups for any of the question scores Three participants said that they would feel confident using the machine after a day of using it or after a period of familiarization One participant felt confident to use the machine in a	It would be preferable to develop practical familiarity with complex new equipment in a safe environment New equipment should be designed both to reduce the likelihood of errors and to increase the early detection of errors that do occur	Anesthesiologists cannot reliably assess their ability to safely use the equipment in clinical practice Simulation provides an excellent opportunity to assess equipment design without exposing patients to potential risk HPS can improve the ability of practitioners to safely

						of the times taken to crisis resolution reviewed by videotape analysis by an independent observer (CC) blinded to group allocation Errors made by study participants during the management of the two clinical crises were recorded	normal case, but not in a crisis Four participants did not feel confident to use the Machine In Scenario A, no errors were made by Group 1 participants, whereas 14 errors were made by Group 2		use new equipment
Weller, J., Merry, A., Warman, G., & Robinson, B. (2007). Anaesthetists' management of oxygen pipeline failure: room for improvement*. *Anaesthesia*, *62*(2), 122-126. https://doi.org/10.1111/j.1365-2044.2006.04899.x	Case control non experimental study (Level 4)	N/A	To establish the benefits of computerized patient simulation in identifying deficits in management of equip	20 anesthetists	Familiarity with anesthesia equipment and recognition of oxygen pipeline supply failure Pre-operative check of their	Direct observation, video recording, and automated monitor printouts (including gas analysis)	All anesthetists maintained ventilation throughout the case 70% had not discovered backup	Behavior in the simulator may not accurately reflect the participants' normal practice	In adequate management of an event by an entire

			ment-related events		equipment		oxygen cylinder was empty pre-operatively Provision of adequate anesthesia during the pipeline failure was variable No anesthetist disconnected the wall pipeline supply		cohort of anesthetists would suggest a fundamental educational problem requiring a specialty-wide response Data strongly suggest that anesthetists ought to be fully

									competent in the management of oxygen failure and that there may be room for improvement.
Mudumbai S.C., Fanning R., Howard, S.K., Davies F.M., & Gaba D.M. (2010). Use of medical simulation to explore equipment failures and human-machine interactions in anesthesia machine pipeline supply crossover. *Anesthesia & Analgesia*, *110*(5), 1292-1296. https://doi.org/10.1213/ANE.0b013e3181d7e097	Prospective Descriptive Study (Level 6)	N/A	To show how high-fidelity medical simulation could both teach anesthesia residents about equipment function and examine their management strategies during an equipment-related crisis	3rd yr anesthesia residents (1– 4 months before graduation) in groups of 2 (n=20)	pipeline O2 and N2O supplied from hose drops auxiliary O2 flowmeter low O2 and high N2O alarms modes of ventilation	Video recordings with microphones	One group was never able to definitively provide O2 to the simulated patient Two groups persisted with the crossed O2 flowmeter 5 groups ensured adequate oxygenation either with an external O2 tank or	Larger sample size and the use of only multiple types of anesthesia machine	May be useful to consider a method such as high-fidelity medical simulation to expose potential causes of these crises and possible better management strategies

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							with air from the anesthesia machine itself only 3 groups recognized the high N2O alarm		
Larson, E.R., Nuttall, G.A., Ogren, B.D., Severson, D.D., Wood, S.A., Torsher, L.C., Oliver, W.C., & Marienau, M.E. (2007). A prospective study on anesthesia machine fault identification. *Anesthesia & Analgesia*, *104*(1), 154-156. https://doi.org/10.1213/01.ane.0000250225.96165.4b	Prospective Study (Level 6)	N/A	To see if there has been any improvement in the ability of practitioners to detect preset anesthesia machine faults and if duration of practice is related to the ability to detect such faults	87 volunteers	Five preset faults: 1. Leak in the water trap 2. Empty oxygen cylinder, 3. Sticky exhalation valve, 4. Dead backup battery 5. Removal of the oxygen/nitrous oxide fail-safe linkage	data collection tool Kruskal–Wallis test pairwise comparisons of the three experience groups	74.7% of subjects detected the leak in the water trap and the empty oxygen cylinder 50.6% and 49.4% found the dead battery and oxygen/nitrous fail-safe linkage disconnect Ten participants succes	Provide familiarization with the provided machine before the test is conducted Prevent risk of communication among participants	There continues to be problems detecting anesthesia machine faults despite the publication of multiple checklist There is a need for continued education of anesthesia personnel regarding detection of anesthe

							sfully found all five faults Three subjects detected zero faults		sia machine faults
Lorraway, P.G., Savoldelli, G.L., Joo, H.S., Chandra, D.B., Chow, R., & Naik, V.N. (2006). Management of simulated oxygen supply failure: Is there a gap in the curriculum? *Anesthesia & Analgesia*, *102*(3), 865-867. https://doi.org/10.1213/01.ane.0000195548.38669.6c	Cohort study (Level 4)	N/A	To evaluate the understanding and management of a simulated oxygen pipeline failure by residents in an anesthesiology training program	20 residents	Recognizes loss of pipeline oxygen supply Recognizes the O2 supply and pressure alarms Opens O2 cylinder on machine Recognizes O2 cylinder is empty Calls for a new O2 cylinder Changes O2 cylinder successfully Ventilates with Ambu bag	Videotaped	Majority of subjects did not attempt to open or change the cylinder even after being prompted by the surgeon None of the subjects responded by increasing the flow of air in the gas machine Most subjects did not recognize the origin of the alarms indicat	The presence of a second group would have helped to draw stronger conclusions.	Oxygen supply failure is poorly understood and suboptimal managed by anesthesiology residents. High-fidelity patient simulation is a useful tool to identify gaps in anesthesia trainee knowledge Patient simulation may be a useful tool to identify areas of weakn

					Anticipates patient awakening		ing an oxygen supply failure. Most subjects did not know how to change the oxygen cylinder or how to open the reserve supply.		ess in a training curriculum in which gaps in knowledge may lead to catastrophic out-comes.
Waldrop, W.B., Murray, D.J., Boulet, J.R., & Kras, J.F. (2009). Management of anesthesia equipment failure: a simulation-based resident skill assessment. *Anesthesia & Analgesia*, *109*(2), 426-433. https://doi.org/10.1213/ane.0b013e3181aa3079	Cohort study (Level 4)	N/A	To develop a set of scenarios that effectively measure skill in managing anesthesia equipment failure and to evaluate the psychometric properties of the participants' scores, including their	56 residents	8 Scenarios: 1) Endotracheal tube cuff rupture 2) Large defect (tear)in plastic disposable gas circuit 3) Loss of central oxygen supply with empty O2reserve cylinders	Time it took until action was completed	Each resident in-creased as a function of training level. The residents with more training and experience were able to accomplish these actions in a shorter period of time	Utilizing residents from various anesthesia programs to limit the generalizability of the results Use more scenarios of the many types of equipment failures	Residents with more training and experience performed better Anesthesia residents should acquire the skills to recognize and manage a number of reported causes of

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			validity and reliability		4) CO_2 absorbent canister misalignment with no gas delivery 5) obstructed endotracheal tube, 6) disconnected Spo2and end-tidal CO_2 monitors with no immediate "patient" problem 7) Inhaled anesthetic (isoflurane) overdose with associated bradycardia and hypotension 8) Absence of the expiratory valve gasket with associat			experienced in anesthesiology	anesthesia equipment failure during residency. Modeling these equipment failures in a simulated environment, reliably evaluate trainees' strengths and weaknesses, providing guidance concerning relevant feedback, and detect potential educational problems in the training program

					ed proximal circuit leak				
Armstrong-Brown, A., Devitt, J.H., Kurrek, M., & Cohen, M. (2000). Inadequate preanesthesia equipment checks in a simulator. *Canadian Journal of Anaesthesia 47*(10), 974-979. https://doi.org/10.1007/BF03024868	Quasi-experimental (Level 3)	N/A	Examine how differences in age or type of practice impacts how anesthesiologists check their equipment.	120 participants	High pressure system Low pressure system Ventilator function Scavenging system Emergency ventilation system Airway equipment and suction	Videotaped	Medical students score on average lower than anesthesia residents or anesthesiologists No correlation between square root transformation of score, age, or years of practice	A more robust, complete checklist and less stringent time constraint	Require anesthesiologists to document what checks they have performed at the start of each case to improve compliance with checking procedure.
Schwid, H.A., Rooke, A., Carline, J., Steadman, R.H., Murrray, W.B., Olympio, M., Tarver, S., Steckner, K., & Wetstone, S. (2002). Evaluation of anesthesia residents using mannequin-based simulation: A multiinstitutional study. *Anesthesiology 97*, 1434-1444. https://doi.org/10.1097/00000542-200212000-00015	Case-control Cohort study (Level 4)	N/A	To assess the validity and reliability of the grading system by measuring construct-related validity to	99 anesthesia residents	diagnostic observations announced time to reestablish ventilation Time laryngoscope is removed from mouth	videotaped	construct-related validity of mannequin-based simulator assessment was supported by an overall improvement	Prevention of selection bias	Use of a short form single-point checklist grading forms is adequate enough to determine reliability and

			determine if the simulator evaluation is a legitimate indicator of performance				in simulator scores		validity of simulator performance
Ekert, J.O., Smith, A.L., Ramsey, C.L., Robinson, N., Love, J., Gothard, P., & Armitage, A.J. (2020). Medical student-led simulation in COVID-19 crisis. *The Clinical Teacher 18*(3), 252-257. https://doi.org/10.1111/tct.13308	Case-control study (Level 4)	N/A	To assess if clinical simulation sessions generated by medical students can improve confidence in healthcare workers	36 participants	Confidence scores	Pre- and post-simulation questionnaire	Respondents reported being significantly more confident after the training in all aspects of managing COVID-19 patients	collect responses from all staff members to generate a larger sample size confidence scales are not an accurate reflection of one's objective performance	Medical students can rapidly design and deliver clinical simulation training sessions for a multi-disciplinary team of hospital staff and significantly increase the confidence of participants in times of crisis
Edwards, S., Lee, M., & Sluman, K. (2018). Student-led simulation: Preparing students for leadership. *Nursing Management.* https://doi.org/10.7748/nm.2018.e1778	observational study (Level 6)	N/A	To determine if student-led simulation provides a	Undefined number of students	Learning outside their comfort zone	Self-reflection Peer Review	Students enjoyed and appreciated student led simula	Provide more time to carry out assessments	Demonstrates that teachers support student input. Studen

			progressive learning environment for later leadership roles, professional development, and provide exposure to future professional role situations		Competence levels Collaborative skills Reaction to being led by peers Challenge in role of student lead Decision making		tion approach and challenges	and write up self-peer assessments Different locations with visible hazards	t led simulation allows students to explore lived experiences Uses students' stories in a way that offers insight into their field of practice and the daily situation they will engage in
Lemarie, P., Vidal, S.H., Gergaud, S., Verger, X., Rineau, E., Barton, J., Parot-Schinkel, E., Hamel, J., & Lasocki, S. (2019). High-fidelity simulation nurse training reduces unplanned interruption of continuous renal replacement therapy sessions in critically ill patients: The simHeR randomized controlled trial. *Anesthesia & Analgesia*, *129*(1), 121-128. https://doi.org/10.1213/ANE.0000000000003581	Randomized Controlled, single-center, open study (Level II)	N/A	To assess if additional nurse training program based on high-fidelity simulation would reduce the rate of interrupted sessions	30 nurses	Stress levels Confidence levels	knowledge questionnaire test Satisfaction with the training and apprehension to begin CRRT evaluated using a numerical scale	Intervention group had better results in the knowledge test Confidence was higher and stress was lower in interventions group	blind study to caregivers or study coordinators to protect from bias Provide equal time for training between contro	Th use of high-fidelity simulation can optimize care delivery in ICU settings and improve patient safety

								l and interv ention nurses	

Appendix E

Pre- and Post-Test Questionnaire

Please answer the following questions as accurately as possible.

1. Last four digits of your Marian student ID ____________________.
2. Which age group most closely applies to you (circle):

   23-26 35-38

   27-30 39+

   31-34
3. Which gender do you identify with (circle):

   Male Female

   Prefer not to answer
4. Which ethnicity(ies) apply to you (circle):

   African American Native American

   Asian/Pacific Islander White/Non-hispanic

   Hispanic Other/Prefer not to answer
5. Marital Status (circle):

   Single Married
6. How many years of ICU experience do you have (circle):

   0-2 6-10

   3-5 10+
7. Approximate hours spent studying per week (circle):

   0-10 31-40

   11-20 41-50

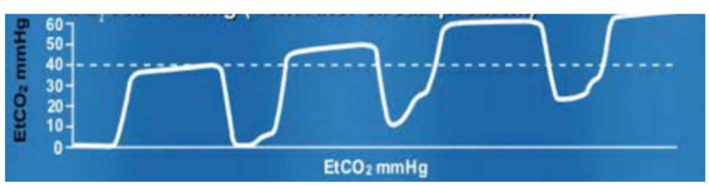
   21-30 51+
8. Approximately how many timer per month do you attend open lab sessions - please indicate the number of sessions attended, not the number of hours (circle):

   0-2 6-10

   3-5 10+

Please answer the following questions to the best of your ability. Circle the correct answer (each question has only one correct answer).

1. What would be an appropriate next action to take in the event of an oxygen pipeline failure?
    a. Disconnect the wall pipeline
    b. Turn on the oxygen cylinder
    c. Ventilate with an ambu bag connected to auxiliary oxygen flowmeter
    d. Increase FiO2 to 100%
    e. Assess the oxygen analyzer for error
2. What would be the first action to take in the event of a gas crossover?
    a. Disconnect wall pipeline
    b. Turn on backup oxygen cylinder
    c. Use an ambu bag that is connected to auxiliary oxygen flowmeter
    d. Increase FiO2 to 100%
    e. Assess the oxygen analyzer for error
3. In the event of a suspected leak, the clinician should begin their search for the leak by:
    a. Inspecting the y piece
    b. Inspecting the integrity of the length of the circuit tubing
    c. Inspecting the circuit to machine connection site
    d. Inspecting the reservoir bag attachment to the machine
4. Your patient's capnography is pictured below. The FiCO2 reads 5 and expired CO2 is 55. What is most likely the cause?



   a. Expired absorbent
   b. Broken expiratory valve
   c. Opioid overdose
   d. Low fresh gas flows

5. During a case, your patient's $FiCO_2$ is increasing steadily. When it reaches 4, your patient's expired CO_2 begins to climb. You know to correct this without jeopardizing the dept of anesthesia or patient safety, you can immediately
   a. Change the CO_2 absorber
   b. Increase the FiO_2 to 100%
   c. Increase the fresh gas flows from 2L to 8L
   d. Decrease the anesthetic gas flow and supplement with IV agents
6. It is important that the backup oxygen cylinder is not left open because:
   a. The machine would utilize the backup O_2 over the pipeline oxygen
   b. If there was an issue with the pipeline, the backup O_2 would be utilized without alarm
   c. Oxygen increases the risk of OR fire and should be contained as much as possible
   d. The backup cylinder should be left open in case of a sudden pipeline failure
7. While transporting an anesthesia machine, one of the vaporizers became dislodged and was tipped over by 30*. The machine should not be put to immediate use because
   a. It could lead to an anesthesia overdose
   b. The vaporizer likely won't have enough gas left in it for a full case
   c. Saturating the bimetallic strip in liquid renders it ineffective
   d. The machine and vaporizer can be used as soon as the vaporizer is locked back into place

8. The CRNA notices a large circuit leak during their morning machine check. They are unable to generate positive pressure when squeezing the reservoir bag. A possible cause of this issue is:
    a. Breathing circuit is occluded
    b. Exhausted CO_2 absorbent
    c. Incompetent oxygen analyzer
    d. Backup O_2 cylinder is opened
    e. APL valve is open or incompetent
9. The breathing circuit is tested during a pre-use machine check for gas flow during inspiration exhalation. Which component of the anesthesia machine is this check assessing?
    a. Oxygen analyzer
    b. Unidirectional valves
    c. Vaporizer
    d. Capnometer
10. T/F: When administering anesthesia on a piston-driven machine, it is important to know that since it is gas-driven, without pipeline oxygen, the machine will quickly drain the O_2 cylinder in order to drive ventilation.
    a. True
    b. False

(continued on the next page)

For the following questions, please answer using the following scale:

1 = Strongly Disagree with the statement
2 = Disagree with the statement
3 = Undecided - neither agree or disagree with the statement
4 = Agree with the statement
5 = Strongly Agree with the statement

1. I feel prepared and confident overall regarding anesthesia machine functionality and safety.

   1 2 3 4 5

2. I am confident that I have mastered anesthesia machine checks.

   1 2 3 4 5

3. I am confident that I can identify anesthesia machine and equipment malfunction and their root cause(s).

   1 2 3 4 5

4. I am confident that I can address and solve an anesthesia machine malfunction.

   1 2 3 4 5

5. I am confident that I can maintain patient safety during an anesthesia machine malfunction and/or failure.

   1 2 3 4 5

6. I am confident that I have an overall mastery of the workings and common failures of anesthesia machines and equipment.

   1 2 3 4 5

7. I feel completely prepared to operate an anesthesia machine in a clinical setting.

   1 2 3 4 5