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The Impact of Anesthesia Machine Check Cognitive Aids on Student Registered Nurse Anesthetist Simulation

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Abstract

Cognitive aids have been shown to enhance clinical performance and improve patient care by increasing the completion of essential tasks and facilitating clinical decision-making. Cognitive aids have also been demonstrated to be effective teaching tools. Simulation is a crucial teaching exercise that allows student registered nurse anesthetists (SRNAs) to practice clinical decision-making without risking patient harm. The anesthesia machine check simulation can be improved by adding cognitive aids. An anesthesia machine check cognitive aid would simplify the learning process and lead to a more productive simulation experience. This project aims to provide SRNAs with anesthesia machine check cognitive aids to assess if this would improve SRNA knowledge, satisfaction, and self-confidence regarding anesthesia machine check simulation exercises. Knowledge was assessed using a five-question test designed to measure anesthesia machine knowledge (Appendix C). SRNA satisfaction and self-confidence were measured using the National League for Nursing's student satisfaction and self-confidence in learning survey (SSSL) (Appendix D). Participants were divided into control and experimental groups. Pretest and posttest knowledge and SSSL survey results were analyzed, and found no statistical significance among the groups ($p < 0.05$). Limitations of this study were the small sample size and poor coordination with the simulation faculty. Further research regarding the implications of cognitive aids in simulation is needed to determine their impact on knowledge, satisfaction, and self-confidence.

Keywords: cognitive aids, simulation, anesthesia machine check, knowledge, satisfaction, self-confidence.

Introduction

Simulation is a significant component of an SRNA's education. Simulation provides a safe environment where an SRNA's clinical knowledge and decision-making skills can be challenged without placing a patient at risk. In a simulation, SRNAs can practice as independent anesthesia providers without the stressful psychological and emotional influences of working with difficult providers, staff members, and patients. Therefore, simulation is an excellent teaching tool for SRNAs to build foundational skills and help assess for potential improvements. Refining simulation through implementing an algorithm-based cognitive aid will facilitate the education of complex concepts. Every anesthesia provider encounters learning the lengthy steps of performing an anesthesia machine check and running through a pre-anesthesia checklist. It is an essential daily task performed by anesthesia providers to ensure the anesthesia machine is ready to provide safe care.

Like the American Heart Association's adult cardiac arrest algorithm, an algorithm-based cognitive aid can be developed to facilitate SRNA anesthesia machine education (American Heart Association, 2020). This revolutionary learning tool can simplify the learning process of memorizing lengthy chronological tasks. A cognitive aid can streamline the anesthesia machine check learning process. This will enable SRNAs to learn this complicated, critical skill with decreased stress, resulting in improved knowledge, satisfaction, and self-confidence. A United Kingdom National Reporting and Learning Service review of 12,606 incidents found that 13% of the incidents reported were related to anesthesia device malfunctions (Catchpole et al., 2008). Anesthesia machine malfunctions and problems can be found by performing a thorough check. Improving the simulation of anesthesia machine checks is also imperative because research studies have found that anesthesia providers of all experience levels still cannot detect all the defects when asked to check a machine with five preset faults (Larson et al., 2007).

This research project aims to determine if an algorithm-based cognitive aid would improve anesthesia machine knowledge, self-confidence, and satisfaction in simulation. An anesthesia machine cognitive aid was developed and only distributed to half of the study's participants. Pretest, posttest, and survey scores were examined and compared between the experimental and control group.

Background

The anesthesia machine is a medical device designed to safely provide oxygen, air, volatile anesthetic agents, and ventilation to patients undergoing surgical procedures (Sherwin & Eisenkraft, 2020). The anesthesia machine is used to titrate inhaled anesthetic gas mixtures to produce ideal surgical conditions and provide patient comfort. Anesthesia machines are complex and can be divided into high, intermediate, and low-pressure systems. The difference in pressures directs the flow of oxygen and other gases. Anesthesia machines safely deliver precise anesthetic gas concentrations using calibrated vaporizers, flowmeters, carbon dioxide absorbers, breathing circuits, and check valves (Sherwin & Eisenkraft, 2020). Anesthesia machine parts must be thoroughly examined through an anesthesia machine check before providing anesthesia care. A faulty component can cause a leak, hypoxic mixture, or other malfunction, putting the patient at risk for harm. Therefore, it is paramount that anesthesia providers perform in-depth anesthesia machine checks to ensure patient safety.

Inadequate anesthesia machine checks are an under-reported problem (Larson et al., 2007). The many different anesthesia machines available in the United States make the implementation of a single anesthesia machine check algorithm challenging. The Food and Drug

Administration (FDA) first issued a recommended pre-anesthesia checklist in 1993 to improve patient safety by promoting thorough anesthesia machine checks (Feldman et al., 2008). In 2008, the American Society of Anesthesiologists (ASA) released “Recommendations for Pre-Anesthesia Checkout Procedures,” a 16-page document with instructions on performing a full anesthesia machine check (Feldman et al., 2008). Despite these resources, many anesthesia providers still perform insufficient machine checks (Larson et al., 2007; Buffington et al., 1984).

Anesthesia providers develop their own routine for performing the anesthesia machine check leading to an increase in unwarranted clinical variance. This variation in machine checks increases the risk that the provider may overlook a defect in the machine. For example, a study of 87 anesthesia providers found that the average anesthesia provider could only find 3.1/5 preset faults when performing an anesthesia machine check (Larson et al., 2007). The same study found that only 10 participants detected all five faults, and 3 found no flaws (Larson et al., 2007). This study reveals the alarming problem that numerous anesthesia providers fail to perform a complete and thorough anesthesia machine check (Larson et al., 2007). A similar study with 190 anesthesia providers at a New York State Society of Anesthesiologists meeting found that 7.3% of participants could not detect any faults. Only 3.4% of the providers could detect all five anesthesia machine faults (Buffington et al., 1984). An example of this problem occurred in Wisconsin when a patient had a coronary artery bypass graft and had to be bag-mask ventilated while the anesthesia machine was swapped out after induction (Ezaru, 2006). The anesthesiologist did not detect a leak from the carbon dioxide absorber because of an incomplete machine check (Ezaru, 2006). The variation in performing an anesthesia machine check leads to incomplete checks putting patients at risk for avoidable, unfortunate events.

The introduction of an algorithm-based cognitive aid for anesthesia machine checks may facilitate the learning process of this critical task and produce anesthesia providers who perform thorough machine checks consistently. Providing SRNAs with an anesthesia machine check cognitive aid will improve the education of this complex task, increasing SRNA knowledge, self-confidence, and satisfaction.

Problem Statement

Anesthesia providers are responsible for ensuring that the anesthesia machine is ready to provide safe care before every procedure. Unfortunately, anesthesia providers may either not be consistent or knowledgeable in performing complete machine checks, increasing the risk of a faulty anesthesia machine being used (Larson et al., 2007). Various studies and anecdotes support the idea that anesthesia providers should receive periodic educational briefings on anesthesia machine checks (Ezaru, 2006; Larson et al., 2007). By developing an anesthesia machine check cognitive aid, anesthesia providers may adopt a more consistent routine of thorough anesthesia machine checks. In addition, improving the anesthesia machine check learning process may lead to novice anesthesia providers becoming knowledgeable in detecting all faults with anesthesia machines when conducting machine checks.

Needs Assessment & Gap Analysis

The project site does not utilize an anesthesia machine check cognitive aid to prepare SRNAs for anesthesia machine check simulation. The project site's practice prepares SRNAs for anesthesia machine check simulation with textbooks, online resources, hands-on practice, and professor instruction. A gap analysis was completed through an examination of the nurse anesthesia program. The gap analysis revealed no utilization of an anesthesia machine check algorithm-based cognitive aid because of a lack of awareness of the educational tool. Research suggests cognitive aids facilitate the learning process and improve knowledge among anesthesia providers (Groves et al., 1994; Suet et al., 2021; Neal et al., 2012).

Literature Review

Search Methodology

This literature review was conducted to examine articles regarding the utilization of algorithm cognitive aid teaching tools to improve anesthesia machine check education in adults studying anesthesia. The review was conducted using the keywords *algorithm, concept map, cognitive aid*, *teaching tool*, *flowchart, anesthesia*, *education*, *simulation*, *knowledge, satisfaction,* and *self-confidence*. This review was conducted in January 2022 using the databases PubMed and Medline-Ovid. The database searches were performed using the BOOLEAN phrases *algorithm OR concept map OR flowchart OR cognitive aid OR teaching tool,* and *anesthesia OR education OR simulation.*

The seven hundred sixty-nine database search results were reduced to exclude secondary research designs, case studies, pediatric patients, and animal research. The remaining research studies were examined to determine if the studies met the inclusion criteria. The search inclusion criteria included articles written or translated into English. Of the seventy-two articles examined, fifty-nine articles were excluded due to unrelated research objectives and case study design. The research articles for this literature review were reduced to 14 level 2 and level 3 studies that emphasized the impact of cognitive aids, algorithms, and checklists on performance, knowledge, and participant perception. The literature review matrix is displayed in Appendix A.

Impact on clinical performance

Twelve of the fourteen studies examined the influence of cognitive aids on clinical performance. Eleven of the twelve studies found that cognitive aids enhanced clinical performance and may facilitate superior patient care by increasing completion of essential tasks and improving clinical decision-making (Beck et al., 2018; Combes et al., 2004; Harrison et al., 2006; Hart & Owen, 2005; Heidegger et al., 2001; Neal et al., 2012; St. Pierre et al., 2017; Ward et al., 1997; Watkin et al., 2016; Wetmore et al., 2016; Zeiwacz et al., 2011). These studies evaluated performance in clinical and simulated settings by assessing numbers of omitted actions and errors. A randomized controlled trial consisting of 25 anesthesiologists participating in a simulated local anesthetic systemic toxicity scenario found that those equipped with the checklist cognitive aid were able to significantly outperform those without ($P<0.001$) (Neal et al., 2012). Participants with the cognitive aid averaged 16 essential tasks completed compared to the control group, who averaged 8.8 (Neal et al., 2012). Another randomized control trial of 26 anesthesia residents in two university hospitals found that implementing a checklist cognitive aid significantly increased the completion of safety checks immediately and four weeks after implementation ($P=0.003$) (Beck et al., 2018). Also, a study evaluating the impact of a cognitive aid on the clinical performance of 48 anesthesia residents during a malignant hyperthermia simulation using a malignant hyperthermia treatment score scale found that the residents who scored the highest were the ones who most frequently relied on the cognitive aid ($P<0.001$) (Harrison et al., 2006). Another simulation study found that implementing an operating room crisis cognitive aid checklist decreased the incidence of missed critical tasks six-fold ($p=0.007$) (Ziewacz et al., 2011). In this study, teams with the cognitive aid missed 2 out of 46 essential steps compared to those without the cognitive aid, who missed 11 crucial steps (Ziewacz et al., 2011). Two observational studies found that implementing a difficult airway cognitive aid resulted in decreased failed intubations (Combes et al., 2004; Heidegger et al., 2001).

Bould et al.'s (2009) neonatal resuscitation simulation randomized control trial was the only research study that resulted in no significant difference in clinical performance between anesthesia residents with and without cognitive aids (Bould et al., 2009). The researchers believed both groups performed similarly due to the experimental group's lack of cognitive aid use (Bould et al., 2009).

All twelve studies evaluating cognitive aid's impact on clinical performance emphasized that further research on the implementation of cognitive aids in anesthesia is weak as most research has been performed in simulated settings. However, evidence provided by studies utilizing cognitive aids in simulation scenarios have found a strong relationship between the use of cognitive aids and improved performance and safety.

Improved Knowledge

Two of the fourteen articles examined the relationship between cognitive aids and participant knowledge (Neal et al., 2012; Suet et al., 2021). Both studies found that groups with cognitive aids had increased medical knowledge gain compared to those without. Neal et al. (2012) examined the knowledge retention of 25 anesthesia residents two months after the distribution of a cognitive aid and observed that those with the aid said scored higher knowledge test scores (P=0.031). Similar findings were found in an 89-anesthesia resident randomized control trial which examined the influence of a cognitive aid on an observer's medical knowledge gain after viewing a simulation scenario (Suet et al., 2021). This study found that those using the cognitive aid scored a mean of 11.4 on the medical knowledge test compared to the control group, who scored 9.6 (P=0.0008) (Suet et al., 2021). This is a critical study because it focused on the cognitive aids' influence on the education of anesthesia residents and found a significant link to improved medical knowledge gain. This study provides evidence that cognitive aids can be used as teaching tools.

Non-technical Skills

Three of the fourteen studies evaluated cognitive aid's effect on the participant's non-technical skills using the Anaesthetists' Non-Technical Skills (ANTS) scoring system (Marshall & Mehra, 2014; Neal et al., 2012; Suet et al., 2021). The ANTS scoring system is a measuring instrument used to assess the degree of team management, teamwork, situational awareness, and decision-making skills (Marshall & Mehra, 2014). A study of 64 participants undergoing a difficult airway simulation found that participants equipped with the cognitive aid had high ANTS scores in every category (p=0.002) (Marshall & Mehra, 2014). The study concluded that cognitive aids enhanced non-technical skills during airway emergencies. Similarly, Neal et al. (2012) analyzed 25 anesthesiologists undergoing a simulation with cognitive aids. They found that the cognitive aid group had higher ANTS decision-making scores averaging 5.2 compared to 4.0 (p=0.037) (Neal et al., 2012). Suet et al.'s (2021) study of 89 anesthesia residents found no difference in ANTS scores between residents who received cognitive aids and those who did not. These three studies reported different findings when measuring cognitive aid's impact on non-technical skills.

Provider Satisfaction

Three of the fourteen studies examined cognitive aid's influence on the participant's satisfaction of the simulation (Hart & Owen, 2005; Suet et al., 2021; Ziewacz et al., 2011). Ziewacz et al. (2011) found that participants with checklist cognitive aid on average felt better prepared for emergencies (4.2+/- 0.95) and would utilize cognitive aids if present in medical centers (4.3+/-0.75). Similar findings were reported in an observational study where 20 anesthesiologists experienced a general anesthesia simulation for cesarean delivery with and without a cognitive aid (Hart & Owen et al., 2005). 95% of participants felt the cognitive aid was helpful, and 80% of participants would want to use the cognitive aid if presented with a simulation again (Hart & Owen et al., 2005). The providers who experience the guidance of cognitive aids agree that they are useful for improving patient care and safety; therefore, increasing provider satisfaction.

Theoretical framework

Kolb's theory of experiential learning was the theoretical framework used for this project (Kolb, 1984). Kolb's theory of experiential learning consists of a learning cycle of four phases: phase 1 concrete experience, phase 2 reflective observation, phase 3 abstract conceptualization, and phase 4 active experimentation (Murray, 2018). Kolb theorized that students must encounter all four stages of learning to learn from their experiences (Murray, 2018).

During this research project, students will undergo the concrete experience phase when simulating an anesthesia machine check by receiving a hands-on, psychomotor experience (Murray, 2018). Next, participants will experience the reflective observation phase when recollecting the simulation experience and reflecting on how they feel about it. Students will encounter the abstract conceptualization phase when critically thinking and making significant intellectual connections regarding anesthesia machine check troubleshooting. Lastly, in the active experimentation phase, the students will practice their new knowledge in simulation or clinical and reaffirm the concepts they learned in the beginning stages. A diagram of Kolb's theory of experiential learning can be seen in Appendix B.

Project Aim

1. The project aim is to determine if an algorithm-based cognitive aid teaching tool will improve anesthesia machine check simulation knowledge, self-confidence, and satisfaction in student registered nurse anesthetists.

Project Objectives

1. Develop an algorithm cognitive aid teaching tool to simplify anesthesia machine check education
2. Provide this tool to the experimental group of students seven days before anesthesia machine check simulation exercise.
3. Design a five-question anesthesia machine check knowledge test (Appendix D) to collect data within 15 minutes before the start of the simulation exercise and again within 10 minutes after.
4. Utilize the National League for Nursing's student satisfaction and self-confidence in learning survey (Appendix D) to collect data within 15 minutes before and 10 mins after the simulation exercise.
5. Perform statistical analysis to examine the differences in knowledge, satisfaction, and self-confidences test scores between both groups, pre- and post-simulation.

Project Design/ Setting/ Population

This project is a quasi-experimental research study designed to examine the relationship between an algorithm cognitive aid teaching tool and SRNA knowledge, satisfaction, and self-confidence in anesthesia machine check simulation. The anesthesia machine simulation exercise would be held in a simulation lab in a nursing school in the Midwest of the United States. A nursing program simulation professor would conduct the simulation exercise. This research project would be conducted using first year, third semester SRNAs recently introduced to an anesthesia machine. The SRNAs will already have a traditional anesthesia machine education through textbooks, online resources, and hands-on opportunities.

Data collection procedure/ Measurement Instruments

The study will consist of an anonymized demographic questionnaire, knowledge, satisfaction, and confidence surveys done before and after the anesthesia machine check exercise. Seven days before the scheduled simulation exercise, thirty-four SRNAs will receive a recruitment email with information on the DNP project. Embedded in this recruitment statement will be a Qualtrics link where potential participants will be directed to the implied consent page. Once participants acknowledge the study's implied consent, the participants will proceed to complete the pre-test consisting of the demographic questionnaire, knowledge test, and satisfaction and self-confidence survey. The demographic questionnaire collects information on the participants' age, gender, marital status, highest level of education, years of clinical experience. Finally, half the participants will be assigned to the experimental group and receive the algorithm cognitive aid teaching tool to study in preparation for the anesthesia machine check simulation. The remaining seventeen participants will be assigned to the control group will be performing the simulation without the cognitive aid. The anesthesia machine check simulation is a mandatory exercise as part of the NSG 607S course. Participation in the DNP project is completely voluntary. Immediately after the simulation exercise, the participants will complete the post-test answering the same questions as the pre-test.

The instrument used to collect the pre- and post-test data is Qualtrics. Participant confidentiality will be maintained throughout the study using Qualtrics’ anonymize setting. The measurement tool used to measure knowledge will be a principal investigator-created 5-question quiz validated by DNP committee members. The measurement tool to be used to evaluate satisfaction and self-confidence will be the National League for Nursing's Student Satisfaction and Self-Confidence in Learning Scale.

Ethical Considerations/Protection of Human Subjects

Involvement in this study was low risk. The students acknowledged the informed consent statement prior to participating in the study. Research project participation was voluntary and did not risk causing physical or mental health concerns. The study utilized anonymous surveys and did not request personal information. The information collected for this study was secured in a password-protected laptop only accessible to the research organizers. Internal Review Board approval was granted before beginning the DNP project.

Project Evaluation Plan

This research project's data collection consisted of demographic information, knowledge test scores, and Student Satisfaction and Self-Confidence in Learning Scale scores before and after the simulation exercise. The Qualtrics software will store all of the data to be translated into a statistical software program. This program will record all quantitative data from the test and survey scores and organize the demographic data into subgroups. A paired t-test will be used to examine pretest and posttest scores within the control and experimental group. An independent samples t-test will be used to evaluate if there is a significant relationship between the implementation of the algorithm cognitive aid and increased knowledge, satisfaction, and self-confidence scores. Using the collective average score of each pre- and post-simulation survey question, independent sample t-test can determine if there is a correlation between the cognitive aid and improved scores.

Data Analysis and Results

Demographics

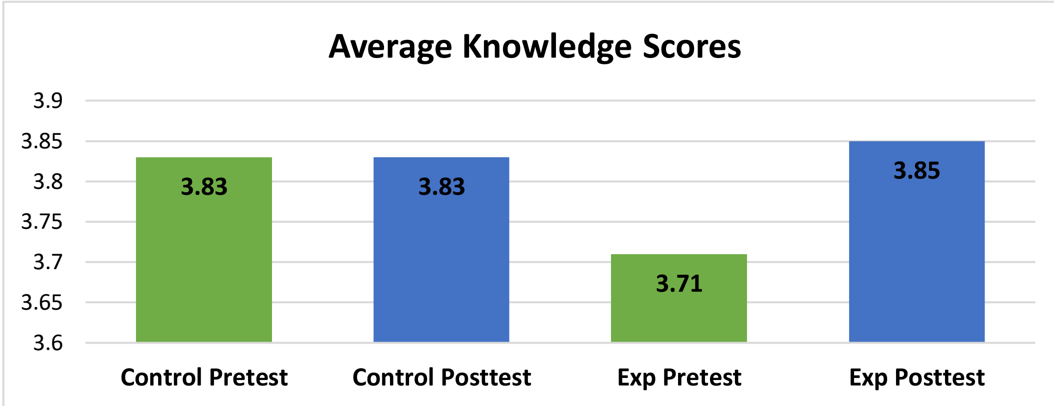
This project consisted of 13 participants who completed the knowledge test, SSSL pretest, and posttest surveys. Of the 13 participants, there were a total of 10 females (77%) and three males (23%). Seven of the 13 participants reported being 26-30 years old (54%), followed by 4 participants reporting being 31-35 years old (31%), and two participants reporting being over 35 years old (15%). In addition, eight participants (62%) reported being single, and five (38%) reported being married. One participant reported having a master's degree (8%), while the remaining 12 participants reported having a bachelor's degree (92%) as their highest level of education. Seven of the participants were randomized into the experimental group (54%) and six were randomized into the control group (46%).

Knowledge Test

The five-item knowledge test was designed to examine the participant's baseline and change in knowledge regarding anesthesia machine checks (Appendix C). The control group's average pretest score was 3.83, and the average posttest score was 3.83. When performing a paired t-test, the results showed no statistically significant change among the control group's pretest and posttest scores ($p > 0.05$). The experimental group's average pretest score was 3.71, and the average posttest score was 3.85. When performing a paired t-test, the results showed no statistically significant change among the experimental group's pretest and posttest scores ($p > 0.05$). The data revealed no statistical significance when performing an unpaired t-test comparing the experimental and control group's posttest scores ($p > 0.05$).

Figure 1

Average knowledge pretest and posttest scores



Control Group Pretest to Posttest Comparison

When performing a paired t-test analysis of the control group's pretest and posttest results, the data revealed that the anesthesia machine check simulation without the cognitive aid resulted in statistically significant improved self-confidence ($p < 0.05$) and an insignificant change in satisfaction ($p > 0.05$). The control group's average satisfaction score increased from 17.5 on the pretest to 20.8 on the posttest ($p > 0.05$). In addition, the control group's average self-confidence scores improved from 29.8 on the pretest to 33.7 on the posttest resulting in a statistically significant change ($p < 0.05$). Of the 13 questions of the SSSL, questions six and eight resulted in a statistically significant change ($p < 0.05$) from the pretest to the posttest. Question six, *I am confident that I am mastering the content of the simulation activity that my instructors presented to me*, had an average pretest score of 3.17 and an average posttest score of 4 ($p < 0.05$). Question eight, *I am confident that I am developing the skills and obtaining the required knowledge from this simulation to perform necessary tasks in a clinical setting,* had an average pretest score of 3.67 and an average posttest sore of 4.33 ($p < 0.05$).

Experimental Group Pretest to Posttest Comparison

When performing a paired t-test analysis of the experimental group's pretest and posttest results, the data revealed an insignificant change in satisfaction scores ($p > 0.05$) and statistically significant improved self-confidence scores ($p < 0.05$). The experimental group's average satisfaction score increased from 19 on the pretest to 21.4 on the posttest ($p > 0.05$). Also, the experimental group's average self-confidence scores improved from 29.5 on the pretest to 34.4 on the posttest, resulting in a statistically significant change ($p < 0.05$). Of the 13 questions of the SSSL, questions six, eight, and 12 resulted in a statistically significant change ($p < 0.05$). Question six, *I am confident that I am mastering the content of the simulation activity that my instructors presented to me*, had an average pretest score of 3.29 and an average posttest score of 4.29 ($p < 0.05$). Question eight, *I am confident that I am developing the skills and obtaining the required knowledge from this simulation to perform necessary tasks in a clinical setting*, had an average pretest score of 3.43 and an average posttest score of 4.29 ($p < 0.05$). Question 12, I know how to use simulation activities to learn critical aspects of these skills, had an average pretest score of 3.71 and an average posttest score of 4.43 ($p < 0.05$).

Comparison of Control and Experimental Group Posttests

The study revealed no statistically significant difference when performing an independent, unpaired t-test comparing the control and experimental group's satisfaction and self-confidence posttest scores ($p > 0.05$). In both posttests, the experimental group had a slightly higher average score, but not enough to be statistically significant. The average experimental group satisfaction and self-confidence posttest score were 21.4 and 34.4, respectively, compared to the control group, which was 20.8 and 33.6.

Figure 2

Average SSSL satisfaction pretest and posttest scores

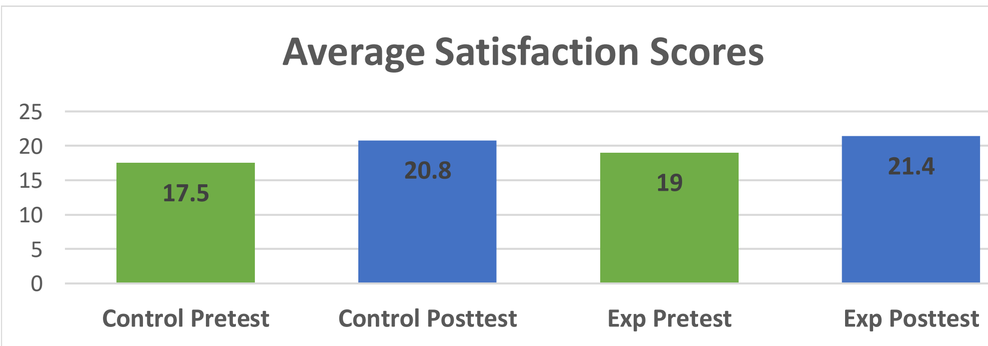
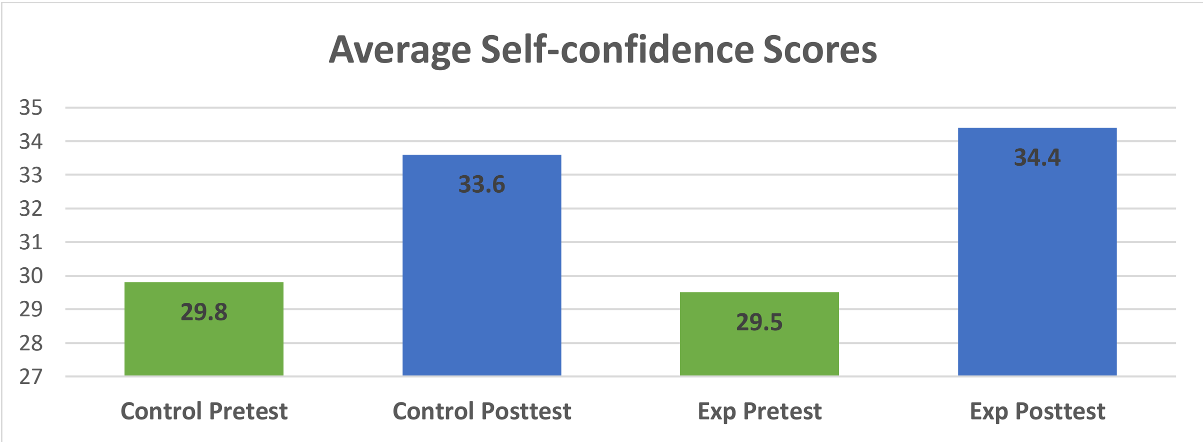


Figure 3

Average SSSL self-confidence pretest and posttest scores



Discussion

The strengths of this project were simple, digital data collection, simulation faculty support, and coordinated anesthesia machine simulation schedule. Limitations of the study were small sample size, flexibility of students to coordinate simulation checkoffs earlier or later than scheduled, potential communication between students participating in the study, and student disinterest in study due to other academic responsibilities. Due to the limitations of this study, it is uncertain if cognitive aids improved SRNA knowledge, satisfaction, and self-confidence. Recommendations for this study are to have improved coordination and participation of the simulation faculty to increase the sample size. Another recommendation is to plan the anesthesia machine simulation exercise at a time when this exercise can be focused on so students are not distracted by concerns for exams occurring shortly after the simulation. Future studies on cognitive aid’s impact on simulation should include larger sample sizes.

Conclusion

Cognitive aids simplify the learning process and make the memorization of crucial information less difficult for the student. An algorithm-based cognitive aid can streamline imperative simulation exercises like anesthesia machine checks. The improved method of education that cognitive aids provide enables SRNAs to participate in simulation with decreased stress, resulting in improved knowledge, satisfaction, and self-confidence. Simulation provides a safe environment where SRNAs can practice as independent anesthesia providers without the risk of patient harm. Therefore, simulation is an excellent educational exercise for SRNAs to build foundational skills and assess for improvements. The addition of cognitive aids may improve the learning process and provide students with better satisfaction and self-confidence after their simulation.

After reviewing the analysis of the knowledge, satisfaction, and self-confidence pretest and posttest scores, the study results are inconclusive. This study did not find a statistically significant relationship between cognitive aids and improved knowledge, satisfaction, or self-confidence for the anesthesia machine check simulation. Further research regarding the benefits of cognitive aids in simulation and anesthesia education is necessary to determine whether these tools can be utilized to improve knowledge, satisfaction, and self-confidence.

References

American Heart Association. (2020). Adult cardiac arrest algorithm. https://cpr.heart.org/-/media/CPR-Files/CPR-Guidelines-Files/Algorithms/AlgorithmACLS_CA_200612.pdf

Beck, S., Reich, C., Krause, D., Ruhnke, B., Daubmann, A., Weimann, J., Zollner, C., Kubitz, J. (2018). For beginners in anaesthesia, self-training with an audiovisual checklist improves safety during anaesthesia induction: A randomised, controlled two-centre study. *European Journal of Anaesthesiology*, *35*, 527-533. https://dx.doi.org/10.1097/EJA.0000000000000781

Bould, M. D., Hayter, M. A., Campbell, D. M., Chandra, D. B., Joo, H. S., & Naik, V. N. (2009). Cognitive aid for neonatal resuscitation: A prospective single-blinded randomized controlled trial. *British Journal of Anaesthesia*, *103*(4), 570–575. https://doi.org/10.1093/bja/aep221

Buffington, C. W., Ramanathan, S., & Turndorf, H. (1984). Detection of anesthesia machine faults. *Anesthesia and analgesia*, *63*(1), 79–82.

Catchpole, K., Bell, M. D., & Johnson, S. (2008). Safety in anaesthesia: A study of 12,606 reported incidents from the UK National Reporting and Learning System. *Anaesthesia*, *63*(4), 340–346. https://doi.org/10.1111/j.1365-2044.2007.05427.x

Combes, X., Le Roux, B., Suen, P., Dumerat, M., Motamed, C., Sauvat, S., Duvaldestin, P., & Dhonneur, G. (2004). Unanticipated difficult airway in anesthetized patients: Prospective validation of a management algorithm. *Anesthesiology*, *100*(5), 1146–1150. https://doi.org/10.1097/00000542-200405000-00016

Ezaru C. S. (2006). Preinduction check-up of the anesthesia machine. *Anesthesia and analgesia*, *102*(5), 1588–1589. https://doi.org/10.1213/01.ANE.0000215201.76420.57

Feldman, J. M., Olympio, M. A., Martin, D., & Striker, A. (2008). New guidelines available for pre-anesthesia checkout. *Anesthesia Patient Safety Foundation*, *23*(1), 6-7. https://www.apsf.org/wp-content/uploads/newsletters/2008/spring/pdf/APSF200803.pdf

Groves, J., Edwards, N., & Carr, B. (1994). The use of a visual aid to check anaesthetic machines. Is performance improved?. *Anaesthesia*, *49*(2), 122–125. https://doi.org/10.1111/j.1365-2044.1994.tb03367.x

Harrison, T. K., Manser, T., Howard, S. K., & Gaba, D. M. (2006). Use of cognitive aids in a simulated anesthetic crisis. *Anesthesia and Analgesia*, *103*(3), 551–556. https://doi.org/10.1213/01.ane.0000229718.02478.c4

Hart, E. M., & Owen, H. (2005). Errors and omissions in anesthesia: a pilot study using a pilot's checklist. *Anesthesia and analgesia*, *101*(1), 246-250. https://doi.org/10.1213/01.ANE.0000156567.24800.0B

Heidegger, T., Gerig, H. J., Ulrich, B., & Kreienbühl, G. (2001). Validation of a simple algorithm for tracheal intubation: daily practice is the key to success in emergencies: An analysis of 13,248 intubations. *Anesthesia and analgesia*, *92*(2), 517–522. https://doi.org/10.1097/00000539-200102000-00044

Kolb, D. A. (1984). Experiential Learning: Experience as the Source of learning and development. *Prentice-Hall*.

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 and analgesia*, *104*(1), 154–156.

Marshall, S. D., & Mehra, R. (2014). The effects of a displayed cognitive aid on non-technical skills in a simulated 'can't intubate, can't oxygenate' crisis. *Anaesthesia*, *69*(7), 669–677. https://doi.org/10.1111/anae.12601

Murray, R. (2018). An overview of experiential learning in nursing education. *Advances in Social Sciences Research Journal*, *5*(1). doi:10.14738/assrj.51.4102

Neal, J. M., Hsiung, R. L., Mulroy, M. F., Halpern, B. B., Dragnich, A. D., & Slee, A. E. (2012). ASRA checklist improves trainee performance during a simulated episode of local anesthetic systemic toxicity. *Regional anesthesia and pain medicine*, *37*(1), 8–15. https://doi.org/10.1097/AAP.0b013e31823d825a

Poore, J. A., Cullen, D. L., Schaar, G. L. (2014). Simulation-Based Interprofessional Education Guided by Kolb's Experiential Learning Theory. *Clinical Simulation in Nursing*, *10*(5) 241-247. Shttps://doi.org/10.1016/j.ecns.2014.01.004.

Sherwin, M. A., & Eisenkraft, J. B. (2020). Anesthesia hazards: what is the role of the anesthesia machine? *International anesthesiology clinics*, *58*(1), 27–31. https://doi.org/10.1097/AIA.0000000000000264

St. Pierre, M., Breuer, G., Strembski, D., Schmitt, C., & Luetcke, B. (2017). Does an electronic cognitive aid have an effect on the management of severe gynecological TURP syndrome? A prospective, randomized simulation study. *BMC anesthesiology*, *17*(1), 72. https://doi.org/10.1186/s12871-017-0365-8

Suet, G., Blanie, A., De Montblanc, J., & Benhamou, D. (2021). Use of an observer tool to enhance observers' learning of anesthesia residents during high-fidelity simulation: A randomized controlled trial. *Simulation in Healthcare: Journal of the Society for Medical Simulation*, 1Advance online publication. https://doi.org/10.1097/SIH.0000000000000584

Ward, P., Johnson, L. A., Mulligan, N. W., Ward, M. C., & Jones, D. L. (1997). Improving cardiopulmonary resuscitation skills retention: effect of two checklists designed to prompt correct performance. *Resuscitation*, *34*(3), 221–225. https://doi.org/10.1016/s0300-9572(96)01069-6

Watkins, S. C., Anders, S., Clebone, A., Hughes, E., Patel, V., Zeigler, L., Shi, Y., Shotwell, M. S., McEvoy, M. D., Weinger, M. B. (2016). Mode of information delivery does not effect anesthesia trainee performance during simulated perioperative pediatric critical events: A trial of paper versus electronic cognitive aids. *Simulation in Healthcare: The Journal of The Society for Medical Simulation*, *11*, 385-393.

Wetmore, D., Goldberg, A., Gandhi, N., Spivack, J., McCormick, P., DeMaria, S. (2016). An embedded checklist in the anesthesia information management system improves pre-anaesthetic induction setup: a randomised controlled trial in a simulation setting. *BMJ Quality & Safety*, *25*, 739-46. https://dx.doi.org/10.1136/bmjqs-2015-004707

Ziewacz, J. E., Arriaga, A. F., Bader, A. M., Berry, W. R., Edmondson, L., Wong, J. M., Lipsitz, S. R., Hepner, D. L., Peyre, S., Nelson, S., Boorman, D. J., Smink, D. S., Ashley, S. W., & Gawande, A. A. (2011). Crisis checklists for the operating room: development and pilot testing. *Journal of the American College of Surgeons, 213*(2), 212–217.e10. https://doi.org/10.1016/j.jamcollsurg.2011.04.031

Appendix A

Literature Review Matrix

Citation	**Research Design & Level of Evidence**	**Population / Sample size n=x**	**Major Variables**	**Instruments / Data collection**	**Results**
Beck, S., Reich, C., Krause, D., Ruhnke, B., Daubmann, A., Weimann, J., Zollner, C., Kubitz, J. (2018). For beginners in anaesthesia, self-training with an audiovisual checklist improves safety during anaesthesia induction: a randomised, controlled two-centre study. *European Journal of Anaesthesiology*, *35*, 527-533. https://dx.doi.org/10.1097/EJA.0000000000000781	Randomized controlled trial; level 2	N=26 anesthesia residents during first month of residency	Completion of essential tasks completed during anesthesia induction	Observations of anesthesia induction immediately, at 4 weeks, and at 8 weeks.	Immediately and 4 weeks after implementation of audiovisual cognitive aid checklist, residents with the cognitive aid had significantly greater number of safety checks compared to the control group with no cognitive aid.
Bould, M. D., Hayter, M. A., Campbell, D. M., Chandra, D. B., Joo, H. S., & Naik, V. N. (2009). Cognitive aid for neonatal resuscitation: a prospective single-blinded randomized controlled trial. *British journal of anaesthesia*, *103*(4), 570–575. https://doi.org/10.1093/bja/aep221	Randomized controlled trial; level 2	N=32 anesthesia residents volunteered for neonatal resuscitation protocol (NRP) simulation.	Clinical performance, frequency of cognitive aid use	Video recordings of NRP exercise were examined by a neonatologist and anesthetist using an approved checklist	The checklist scores were not significantly different. There was infrequent use of the NRP cognitive aid by the experimental group.
Combes, X., Le Roux, B., Suen, P., Dumerat, M., Motamed, C., Sauvat, S., Duvaldestin, P., & Dhonneur, G. (2004). Unanticipated difficult airway in anesthetized patients: prospective validation of a management algorithm. *Anesthesiology*, *100*(5), 1146–1150. https://doi.org/10.1097/00000542-200405000-00016	Non-experimental observational study; level 3	N=41 anesthesiologists who have received a 2-month educational period on a difficult airway algorithm with cognitive aid.	Total of intubations, difficult airways, deviations from the algorithm, number of laryngeal mask airways used, algorithm adherence rate, patient medical history, and airway management complications	Medical record review	With the use of the difficulty airway algorithm for 18-month period, 98 unexpected difficult airways were resolved with waking the patient, inserting an LMA, or intubating with bougie.

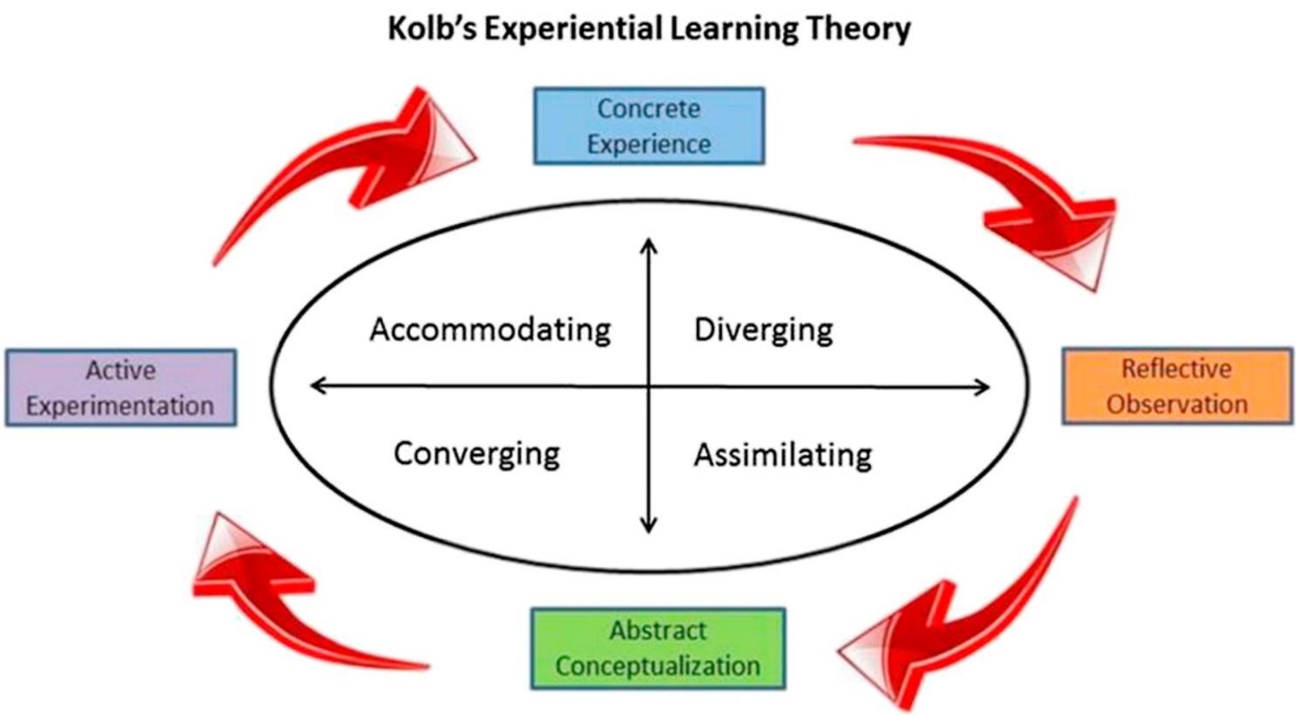
Harrison, T. K., Manser, T., Howard, S. K., & Gaba, D. M. (2006). Use of cognitive aids in a simulated anesthetic crisis. *Anesthesia and Analgesia*, *103*(3), 551–556. https://doi.org/10.1213/01.ane.0000229718.02478.c4	Non-experimental observational study; level 3	N=48, 24 first year anesthesia residents and 24 second year anesthesia residents who volunteered to participate in malignant hyperthermia simulation	Clinical performance, frequency of cognitive aid use	Video recordings were examined using the Malignant Hyperthermia treatment score scale.	The incidence of cognitive aid use was linked to significantly greater MH treatment score for the first year resident group (Spearman r = 0.59, P < 0.01) and second year resident group (Spearman r = 0.68, P < 0.001).
Hart, E. M., & Owen, H. (2005). Errors and omissions in anesthesia: a pilot study using a pilot's checklist. *Anesthesia and analgesia*, *101*(1), . https://doi.org/10.1213/01.ANE.0000156567.24800.0B	Non-experimental observational study; level 3	N=20 anesthesiologists who participated in a general anesthesia for cesarean delivery simulation with an electronic cognitive aid.	Number of tasks not completed feelings about the checklist	Direct observation and anonymous post-exercise questionnaire	Participants missed a median of 13 (range, 7-23) of 40 tasks on the checklist. 95% participants felt that the checklist was useful. 80% would like to use it for practicing simulated scenarios. A checklist cognitive aid would improve patient safety by preventing vital checks from being missed.
Heidegger, T., Gerig, H. J., Ulrich, B., & Kreienbühl, G. (2001). Validation of a simple algorithm for tracheal intubation: daily practice is the key to success in emergencies--an analysis of 13,248 intubations. *Anesthesia and analgesia*, *92*(2), 517–522. https://doi.org/10.1097/00000539-200102000-00044	Non-experimental observational study; level 3	N=80 physician and nurse anesthetists	Number of intubations, type of intubation, surgical procedure, laryngoscopy grade, case details	Filemaker Pro 3.0 database	Implementation of an algorithm lead to 6 failed intubations out of 13,248 cases (0.045%; 95% confidence interval 0.02%-0.11%). An algorithm cognitive aid for endotracheal intubation can lead to reliable successful intubations.
Marshall, S. D., & Mehra, R. (2014). The effects of a displayed cognitive aid on non-technical skills in a simulated 'can't intubate, can't oxygenate' crisis. *Anaesthesia*, *69*(7), 669–677. https://doi.org/10.1111/anae.12601	observational study; level 3	N=64 anesthesia residents	Non-technical skills	Anaesthetists' Non-Technical Skills (ANTS)	Anaesthetists' Non-Technical Skills (ANTS) scores were superior in all sections when a cognitive aid was supplied 10.4 (3.1) vs. 13.2 (2.4). The establishment of an infraglottic airway within 3 min in the cognitive aid group was also higher (control group 55.3% vs. intervention 76.9%, p = 0.076). Non-technical skills are enhanced when a cognitive aid is implemented during airway emergencies
Neal, J. M., Hsiung, R. L., Mulroy, M. F., Halpern, B. B., Dragnich, A. D., & Slee, A. E. (2012). ASRA checklist improves trainee performance during a simulated episode of local anesthetic systemic toxicity. *Regional anesthesia*	Randomized controlled trial; level 2	N=25 anesthesiologists, 13 without checklist	Number of tasks completed, knowledge,	Participants were evaluated using the ASRA	Checklist cognitive aid group displayed greater medical management of the simulated LAST event. The checklist group correctly performed 16.0 (2.6) tasks versus the no-checklist group's

and pain medicine, *37*(1), 8–15. https://doi.org/10.1097/AAP.0b013e31823d825a		cognitive aid and 12 with.	nontechnical skills	checklist, knowledge post-test, Anesthetist's non-technical skill (ANTS) scoring system	8.8 (3.0) tasks (mean [SD], P < 0.001). The checklist group had superior decision-making scores on the anesthesiologists' nontechnical skills assessment (5.2 [1.8] versus 4.0 [1.35] summed rater score, P = 0.037) and had higher knowledge retention 2 months later (P = 0.031).
St Pierre, M., Breuer, G., Strembski, D., Schmitt, C., & Luetcke, B. (2017). Does an electronic cognitive aid have an effect on the management of severe gynaecological TURP syndrome? A prospective, randomised simulation study. *BMC anesthesiology*, *17*(1), 72. https://doi.org/10.1186/s12871-017-0365-8	Randomized controlled trial; level 2	N=20 participants who were anesthesia providers, nurses, and physicians who were all part of anesthesia teams	Completion of essential tasks, influence of cognitive aid	Observation of simulation, checklist of essential tasks, survey of the influence of the cognitive aid	The cognitive aid group considered evidence-based treatment steps significantly more frequent than teams of the control group (p < 0.001).
Suet, G., Blanie, A., De Montblanc, J., Benhamou, D. (2021). Use of an observer tool to enhance observers' learning of anesthesia residents during high-fidelity simulation: a randomized controlled trial. *Simulation in Healthcare: The Journal of The Society for Medical Simulation*, https://dx.doi.org/10.1097/SIH.0000000000000584	Randomized controlled trial; level 2	N=89 anesthesia residents, 44 with the cognitive aid and 45 without.	Knowledge, stress level, non-technical skills questionnaire	Pre- and post-test for knowledge, researcher designed stress questionnairee, Anesthetist's non-technical skill (ANTS) scoring system	The mean medical knowledge score was higher in the cognitive aid group (P = 0.0008). The mean Anesthetists' Non-Technical Skill score and level of stress perceived did not differ between groups. Both groups reported equal the learning value and satisfaction related to the simulation course.
Ward, P., Johnson, L. A., Mulligan, N. W., Ward, M. C., & Jones, D. L. (1997). Improving cardiopulmonary resuscitation skills retention: effect of two checklists designed to prompt correct performance. *Resuscitation*, *34*(3), 221–225. https://doi.org/10.1016/s0300-9572(96)01069-6	Randomized controlled trial; level 2	N=169 undergraduate students	Completion of essential tasks, accuracy of compressions and ventilations	Researchers recorded completed tasks, and manikin recorded accuracy of compressions and ventilations.	The lengthy checklist cognitive aid group had superior performance on the procedural variables. The results support the hypothesis that cognitive aids help participants remember CPR steps.
Watkins, S. C., Anders, S., Clebone, A., Hughes, E., Patel, V., Zeigler, L., Shi, Y., Shotwell, M. S., McEvoy, M. D., Weinger, M. B. (2016). Mode of information delivery does not effect anesthesia trainee performance during simulated perioperative pediatric critical events: a trial of paper versus electronic cognitive aids. *Simulation*	Randomized controlled trial; level 2	N=89, 45 student registered nurse anesthetists, 44 anesthesia residents	Completion of essential tasks, duration of simulation	Scenario-specific checklists	About 1/3 of anesthesia residents assigned to use a cognitive aid (CA) (electronic 29%, paper 36%) chose not to use it during the scenario. The total score was 6% higher in the paper CA group

in Healthcare: The Journal of The Society for Medical Simulation, *11*, 385-393.					and 8% higher (*P* = 0.03) in the electronic CA group.
Wetmore, D., Goldberg, A., Gandhi, N., Spivack, J., McCormick, P., DeMaria, S. (2016). An embedded checklist in the anesthesia information management system improves pre-anaesthetic induction setup: a randomised controlled trial in a simulation setting. *BMJ Quality & Safety*, *25*, 739-46. https://dx.doi.org/10.1136/bmjqs-2015-004707	Randomized controlled trial; level 2	N=38 anesthesiology residents	Completion of essential tasks, duration of simulation	Pre-anesthetic Induction Patient Safety Checklist	The checklist cognitive aid group scored significantly higher checklist scores by 7.8 points ($p<0.01$). Simulation duration was increased significantly by the use of the checklist in the experimental group.
Ziewacz, J. E., Arriaga, A. F., Bader, A. M., Berry, W. R., Edmondson, L., Wong, J. M., Lipsitz, S. R., Hepner, D. L., Peyre, S., Nelson, S., Boorman, D. J., Smink, D. S., Ashley, S. W., & Gawande, A. A. (2011). Crisis checklists for the operating room: development and pilot testing. *Journal of the American College of Surgeons*, *213*(2), 212–217.e10. https://doi.org/10.1016/j.jamcollsurg.2011.04.031	Quasi-experimental study; level 3	N=11, 2 surgical teams consisting of surgical physicians, residents, anesthesiologists, anesthesia residents, and circulating nurses	Completion of essential tasks, perceptions of checklist cognitive aid	Video recording, simulation checklist	The Checklist cognitive aid group had a 6-fold decrease in omitted steps and errors. 11 of 46 fail steps in the control group compared to 2 of 46 in the cognitive aid group ($p = 0.007$).

Appendix B

Theoretical Framework: Kolb's Theory of Experiential Learning



Poore, J. A., Cullen, D. L., Schaar, G. L. (2014). Simulation-based interprofessional education guided by Kolb's Experiential Learning Theory. *Clinical Simulation in Nursing, 10*(5), 241-247. https://doi.org/10.1016/j.ecns.2014.01.004.

Appendix C

Anesthesia Machine Check Knowledge test

1. Which is most common site for anesthesia machine circuit disconnection?
    a. Defective absorber cannister
    b. Reservoir bag
    c. Y-piece
    d. Inspiratory limb

2. Which of the following is a common cause for anesthesia machine circuit leak?
    a. Defective absorber cannister
    b. Leak in bellows
    c. Oxygen analyzer
    d. Defective flowmeter

3. During high pressure leak tests, breathing circuit should be able to maintain a minimum of?
    a. 70 mmHg
    b. 50 mmHg
    c. 30 mmHg
    d. 20 mmHg

4. Gas pipeline pressures should be a minimum of ______.
    a. 45 psi
    b. 50 psi
    c. 35 psi
    d. 25 psi

5. The oxygen analyzer should detect the inspired oxygen concentration is?
    a. 15%
    b. 30%
    c. 21%
    d. 25%

Dosch, M. P & Tharp, D. (2021). *The Anesthesia Gas Machine*. University of Detroit Mercy – Nurse anesthesia. https://healthprofessions.udmercy.edu/academics/na/agm/index.htm

Nagelhout, J. J. & Elisha S. (2017). *Nurse Anesthesia*. (6th ed.). Elsevier.

Appendix D

Student Satisfaction and Self-Confidence in Learning

Instructions: This questionnaire is a series of statements about your personal attitudes about the instruction you receive during your simulation activity. Each item represents a statement about your attitude toward your satisfaction with learning and self-confidence in obtaining the instruction you need. There are no right or wrong answers. You will probably agree with some of the statements and disagree with others. Please indicate your own personal feelings about each statement below by marking the numbers that best describe your attitude or beliefs. Please be truthful and describe your attitude as it really is, not what you would like for it to be. This is anonymous with the results being compiled as a group, not individually.

Mark:
1 = STRONGLY DISAGREE with the statement
2 = DISAGREE with the statement
3 = UNDECIDED - you neither agree or disagree with the statement
4 = AGREE with the statement
5 = STRONGLY AGREE with the statement

Satisfaction with Current Learning	SD	D	UN	A	SA
1. The teaching methods used in this simulation were helpful and effective.	O 1	O 2	O 3	O 4	O 5
2. The simulation provided me with a variety of learning materials and activities to promote my learning the medical surgical curriculum.	O 1	O 2	O 3	O 4	O 5
3. I enjoyed how my instructor taught the simulation.	O 1	O 2	O 3	O 4	O 5
4. The teaching materials used in this simulation were motivating and helped me to learn.	O 1	O 2	O 3	O 4	O 5
5. The way my instructor(s) taught the simulation was suitable to the way I learn.	O 1	O 2	O 3	O 4	O 5
Self-confidence in Learning	**SD**	**D**	**UN**	**A**	**SA**
6. I am confident that I am mastering the content of the simulation activity that my instructors presented to me.	O 1	O 2	O 3	O 4	O 5
7. I am confident that this simulation covered critical content necessary for the mastery of medical surgical curriculum.	O 1	O 2	O 3	O 4	O 5
8. I am confident that I am developing the skills and obtaining the required knowledge from this simulation to perform necessary tasks in a clinical setting	O 1	O 2	O 3	O 4	O 5
9. My instructors used helpful resources to teach the simulation.	O 1	O 2	O 3	O 4	O 5
10. It is my responsibility as the student to learn what I need to know from this simulation activity.	O 1	O 2	O 3	O 4	O 5
11. I know how to get help when I do not understand the concepts covered in the simulation.	O 1	O 2	O 3	O 4	O 5
12. I know how to use simulation activities to learn critical aspects of these skills.	O 1	O 2	O 3	O 4	O 5
13. It is the instructor's responsibility to tell me what I need to learn of the simulation activity content during class time..	O 1	O 2	O 3	O 4	O 5

National League for Nursing. (2005). *Student Satisfaction and Self-Confidence in Learning*. https://www.nln.org/docs/default-source/default-document-library/instrument-2_satisfaction-and-self-confidence-in-learning.pdf?sfvrsn=0