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Original Research

Development and Use of an Induction of General Endotracheal Anesthesia Checklist Assessment for Medical Students in a Clinical Setting During Their Introductory Anesthesiology Clerkship

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Introduction

Medical students' clinical skills development has been threatened by institutional, economic, and regulatory influences.[1,2] In addition, the specialization of care at academic tertiary care centers reduces students' opportunities to participate in basic hands-on learning.[1] Concerns for clinical skills deficiencies in medical students and junior residents have been reported.[3,4] As a result, the Association of American Medical Colleges (AAMC) Clinical Skills Task Force recommended the adoption of a generic clinical method (defined as "a basic set of elementary clinical tasks or competencies") that should include 12 clinical practice competencies covering the ability to perform basic clinical procedures and application of clinical care to real situations.[1] More recently, the AAMC created 13 Core Entrustable Professional Activities (EPA) by reorganizing "competencies into observable units of clinical work by function" in order to create a roadmap for transitioning medical students to residency.[5] EPA 12 is "perform general procedures of a physician," which includes basic cardiopulmonary resuscitation, bag-mask ventilation, and insertion of an intravenous line[6]: procedures that anesthesiologists perform regularly. As such, anesthesiologists are well-positioned to fill medical students' procedural skills gap.[7,8] In fact, anesthesiology clerkships provide medical students with knowledge and practice in vital clinical skills that are translatable to all medical specialties.[7,9,10] Although there is no official anesthesiology clerkship curriculum consensus, a survey of medical student clerkship directors revealed common clinical activities, including history and physical examination and assessment, peripheral intravenous line (PIV) placement, central line placement, arterial line placement, airway management, and medication administration.[7] After revamping their 4-week anesthesiology clerkship to include assigned faculty teachers and a more structured schedule, Galway[9] administered a post-clerkship survey (n = 25), which indicated that 84% (n = 21) of medical students enjoyed the experience and 72% (n = 18) of medical students strongly believed that the clerkship taught "important skills applicable to all fields." In a 2016 survey of University of Alberta medical students, more than 80% (n = 181) of third- and fourth-year students (n = 226) believed "knowledge of anesthesia was essential."[11] Unfortunately, only 18% of anesthesiology clerkships are a mandatory part of the clinical curriculum in U.S. medical schools[12] and last only approximately 1.7 weeks,[13] compared with mandatory clerkships such as internal medicine, which last approximately 9.1 weeks.[14] In a recent survey of directors of anesthesiology clerkships affiliated with residency programs, 65% (n = 85) reported curriculum time constraints as a barrier to increasing their presence in the curriculum.[7]

Despite anesthesiology's unique clinical learning environment that allows medical students to practice procedures safely, anesthesiology clerkship assessments are generally done in the form of multiple-choice testing,[7] which has its limitations.[15] Studies using checklists to assess students' and trainees' critical care and airway skills have been primarily performed in simulation centers.[16–18] Notably, Hallikainen et al[18] created an extensive checklist for induction of anesthesia with 40 criteria to assess medical students' skills learned during their rotation and compared simulation training versus traditional clinical training. However, the final assessment was performed in the simulation setting. We are aware of only 1 study in which anesthesiology residents were evaluated in the clinical setting, but this study used a nontechnical skills assessment checklist.[19] Considering

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the available literature, we argue that if the goal is to have medical students and anesthesiology trainees achieve a level of proficiency in procedural skills in a real-life clinical setting rather than a simulated one, the assessment should occur in the corresponding environment.

The University of Minnesota (UMN) Department of Anesthesiology offers an elective 2-week introductory anesthesiology clerkship for third- and fourth-year medical students who have completed either the core medicine or surgery clerkship. Annually, approximately 60 to 80 medical students participate in this clerkship. Before the start of the clerkship, medical students are given access to learning materials online (Canvas Learning Platform, Salt Lake City, UT), including a PowerPoint (Microsoft, Seattle, WA) outlining the key steps for induction of general anesthesia and the Checklist used to assess medical students during an induction of general anesthesia with endotracheal intubation (GETA). On the first day of the clerkship, the medical students participate in an orientation that includes time in the simulation center with an anesthesiology attending faculty member practicing PIV placement, mask ventilation, and intubation. Individually, they proceed to a simulated operating room (OR) with a high-fidelity mannequin (SimMan 3G; Laerdal, Stavanger, Norway) to induce GETA, and are debriefed afterward. During the rotation, most of the clinical time is spent paired with anesthesiology residents or attendings in the OR caring for patients. On average, they participate in 15 to 20 general anesthesia inductions. Toward the end of the clerkship, an anesthesiology attending uses the Checklist to assess the medical student while the medical student performs an induction of GETA in the OR. Another anesthesiology attending faculty member, anesthesiology resident, or nurse anesthetist is present to provide immediate assistance when needed. Feedback is provided afterward.

The purpose of this study is to optimize and use the Checklist to assess medical students' skills learned in the clinical setting during their introductory anesthesiology clerkship and gain insight into the efficacy of our curriculum.

Methods

Checklist Development

We examined other checklists published.[17,18] Next, we developed the Checklist by aligning its components with the course learning objectives and AAMC objectives as evidence to support its validity[20] (Table 1). Then, we had UMN anesthesiology physician educators who are actively involved in medical student education and curriculum development evaluate the Checklist for comprehensiveness and feasibility to ensure face validity. The Checklist was modified based on the feedback from those educators. We then piloted the Checklist in the OR and simulation center with medical students and subsequently modified it. Modifications in Checklist items, such as the addition of "application of eye protection," were made after feedback from those educators. Modifications after the Checklist pilot included changes in wording of multiple "prompt" questions as well as the addition of "completed after neutral prompt" in the "score 2" category.

Data Collection

This study was submitted to the UMN Institutional Review Board and was deemed not human research, as the use of the Checklist is part of the usual clerkship activities. Using a pre- and post-clerkship study design we used the Checklist to determine the efficacy of our curriculum. Third- and fourth-year medical students who were enrolled in the introductory anesthesiology clerkship between November 2020 and June 2021 took part in the study. Before starting the clerkship, students were given access to an online Internet resource (Canvas Learning Platform) that contained a PowerPoint presentation. The presentation addressed the different steps of general anesthesia induction/intubation and was created to provide medical students with a basic understanding of the subject. As part of their orientation, the medical students participated in a simulation on the first day of the clerkship. This simulation was videotaped to allow for later assessment to determine baseline performance. All medical students had previously signed a release for filming at the M Simulation Center. Toward the end of the clerkship, students took part in a live clinical scenario during which they performed induction and endotracheal intubation on a patient according to the steps from the Checklist.

Five investigators (I.F., E.Z., I.C., B.K., and W.N.) served as Checklist facilitators who supervised the orientation simulation. Video tapes of the orientation simulation were later reviewed and rated independently by 2 investigators (W.N. and B.K.). The same 2 investigators (W.N. and B.K.) served as Checklist facilitators and raters for the live clinical scenario. Scoring of the Checklist during the live clinical scenarios occurred in real time. When both investigators were present for the live clinical scenario, both debriefed immediately after its conclusion and graded based on mutual agreement. One assessor was pre-assigned the main assessor to resolve disagreements.

Before the study start, live clinical scenarios were practiced with other clerkship medical students to identify confounding factors and optimize response process.[20] It was noted that OR staff and the assigned anesthesia care team occasionally interfered in different steps of the induction process. In addition, staff sometimes provided verbal and/or nonverbal cues. Based on the training experience, the live clinical scenario Checklist facilitators developed a process in which the anesthesia care team was extensively informed about the study and isolated during the induction process to avoid any interference.

Post-Clerkship Survey

Medical students filled out a post-clerkship survey (MedHub, Minneapolis, MN) with Likert scale survey questions and free text questions (Appendix 1). W.N. coded the data from the free text answers by deducing the answers to a summative attribute and categorizing them into groups for tabulation.[21]

Statistical Analysis

All analyses were completed using R version 3.6.3 (Vienna, Austria). The agreement between overall scores was evaluated with single-measurement, 2-way mixed-effects intraclass correlation coefficients (ICC) for both absolute agreement and consistency.[22] The agreement for individual Checklist components was evaluated

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using Krippendorf's alpha, and absolute agreement with 95% bootstrap percentile intervals calculated with 1000 bootstrap iterations for case resampling. ICC and agreement were calculated only for the orientation simulation when there were 2 independent assessors. When there was more than 1 assessor for the clinical scenario, the assessors came to a mutual agreement regarding the final score. We compared the baseline and final Checklist scores by using paired *t*-tests. A $P < .05$ was considered statistically significant.

Results

The final Checklist (Figure 1) contains 10 items. Each item is rated on a scale from 0 to 2 points, with 20 points being the highest score achievable. For each item, 2 points indicates that the medical student did not require the designated prompt to complete the task. If the medical student is unsure or names the incorrect next step, then the designated prompt is given. If the medical student completes the next appropriate step after the prompt, then 1 point is awarded. If the medical student is unable to say or do the next appropriate step, the facilitator tells the medical student what the next step is or gives them another prompt or hint, and 0 points are awarded.

The Checklist study period was from November 23, 2020, to June 24, 2021. Thirty of 45 medical students' clinical Checklist assessments aligned with the availability of a study rater (W.N., B.K. or both). Before statistical analysis, 2 medical students were removed from the study because the faculty simulator facilitator omitted 2 or more prompts, making the baseline simulations challenging to interpret. There were 12 third-year and 18 fourth-year medical students. Eight of the fourth-year medical students took the clerkship at the beginning of their fourth year. Participants were 50:50 men to women. The ICC for agreement was 0.875 (95% confidence interval [CI], 0.704–0.944). The ICC for consistency was 0.897 (95% CI, 0.795–0.950).

Regarding individual levels of agreement for each Checklist item, Checklist item 9 ("Secure the ETT") had the highest Krippendorf's alpha and Cohen's weighted kappa values of 1.00 and 0.94, respectively, and a 96.7% agreement (Table 2). Checklist item 4 ("Announce that the patient is ready for induction") had the lowest values, with an alpha value of 0.65 and kappa of 0.65, but with a percent agreement of 96.7%; 1 rater assigned 2s for 29 students, and the other assigned 28 2s. Checklist item 7 ("Laryngoscopy and Intubation") had no variability for one of the raters, so Krippendorf's alpha and Cohen's weighted kappa could not be calculated. The overall percent agreement was 96.7%. Checklist item 5 ("Mask ventilation technique and measures taken to improve MV") had the lowest percent agreement of 63.3% with a range of 46.7 to 80.0%, but with an alpha of 0.76 and kappa of 0.80 (Table 2).

The mean (SD) baseline Checklist score performed in simulation was 15.1 (2.2). The mean (SD) final Checklist score performed in the clinical environment was 18.7 (1.1). The mean (SD) change from baseline to final score was 3.6 (2.2), which was a statistically significant improvement (95% CI, 2.5–5.2; $P = .001$). A sensitivity analysis using just B.K.'s or just W.N.'s scores did not change the results.

Twenty-seven medical students completed the department-specific survey. All indicated that they agreed or strongly agreed that they were able to participate in procedures. Regarding the open-ended question of what they will incorporate into their future practice as physicians, 19 students answered. Of the 31 comments, 18 were related to the practice of procedural skills including airway management and line placement skills.

Discussion

The point estimate ICC for agreement of 0.875 suggests a good level of agreement. The lower CI of 0.704 also supports moderate agreement between evaluators.[22] The ICC for consistency point estimate of 0.897 suggests good consistency between evaluators.[22] The lower CI of 0.795 also suggests good consistency between evaluators. Based on the 2 ICC estimates, our results suggest that there is moderate absolute agreement and good consistency.[22]

Regarding individual Checklist items, Checklist item 9 ("Secure the ETT") has excellent agreement (Table 2). Regarding Checklist item 7 ("Laryngoscopy and Intubation"), although an alpha and kappa could not be calculated because of the lack of variability of one of the raters, the overall percent agreement of 96.7% suggests high agreement. However, percent agreement does not account for the potential for agreement by chance. Checklist item 4's ("Announce that the patient is ready for induction") low alpha and kappa is likely due to limited variability, but the high percent agreement suggests a high level of agreement. Checklist items 5 ("Mask ventilation technique and measures taken to improve MV") and 6 ("Application of eye protection") have good agreement for their estimates, but only moderate agreement based on the lower confidence limit.

The statistically significant positive change in pre- and post-clerkship Checklist results suggests that medical students gained knowledge and clinical skills from their simulation training in addition to their experience during the clerkship and were able to successfully and safely apply them in a clinical environment. Using a checklist in the clinical environment obviates the inferences required of an assessment in a simulation environment.[20] Because of the clerkship learning objectives and ease of use in the clinical setting, the Checklist was distilled to the most essential aspects of an induction of GETA. The goal was not for medical students to become completely competent in an induction of anesthesia, but to show improvement and have an understanding of the most important induction steps.

The survey results suggest that medical students received hands-on training in the clinical environment, and that the training will enhance these future physicians' understanding of general anesthesia induction and airway management.

Assessment of medical students in the clinical arena is problematic, as it is subject to biases including gender and racial biases.[23–26] As a result, medical schools are increasingly changing the core clerkship grades from a scaled score to a pass/fail.[26] Our institution shifted to the pass/fail system for the core clerkships starting with the 2021–2022 academic year. Even in a pass/fail system, using a checklist in the clinical setting can provide objective data in order to give feedback and ensure

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medical students achieve competency in EPA 12: Performing general procedures of a physician.[1]

Simulation remains a good starting point for training medical students and trainees. Learning in a simulation environment remains crucial and necessary for rare, critical events such as anaphylaxis and unanticipated difficult airways. However, to learn and practice lifesaving procedures that are performed on a routine basis in the OR, anesthesiologists are well-positioned to help medical students attain a level of familiarity and knowledge and to assess those newly acquired skills in the clinical setting.

Study Limitations

Because of hospital regulations regarding the use of video recordings in the OR, we were not able to record the Checklist assessments in the clinical setting. Therefore, assessments had to be made in real time and may be subject to recall bias if the Checklist could not be filled out immediately. Ideally, having the same 2 raters (instead of 1) available every time would mitigate this effect. A significant amount of coordination was needed to facilitate the clinical assessment including the availability of an appropriate patient without anesthesia-related comorbidities, the absence of other learners, whether the procedure necessitated an endotracheal tube, and the availability of at least 1 study rater with minimal or no other clinical responsibilities. Multiple practice sessions were needed to "standardize" the clinical situation in the OR as much as possible. For example, other anesthesiologists, anesthesiology residents, or nurse anesthetists present may consciously or subconsciously give the medical student verbal or visual cues regarding the next step. Therefore, the rater must anticipate and ask the medical student what the next the step is before those cues become apparent.

Future Direction

In our study, we were able to develop a checklist for the induction of GETA and implement it in both the simulation and OR settings. We used the Checklist to generate a pre-rotation and post-rotation score to evaluate whether a medical student's knowledge of general anesthesia induction improved during their introductory anesthesiology clerkship. For future studies, we plan to add a follow-up to evaluate long-term retention of content learned during the rotation and to use audio recordings during the post-rotation live clinical scenario to reduce rater recall bias and allow performance review at a later point. The successful implementation of our Checklist could serve as a model for the development of other checklists for other procedures and/or specialties. Furthermore, the Checklist itself could be modified to become applicable for resident education.

Conclusion

We successfully optimized and used our Checklist to assess medical students' understanding of an induction of GETA in the OR. Medical students gained skills in airway management and a better understanding of the different components of general anesthesia induction during our clerkship. We are not aware of any other published studies that use a checklist to assess learners' airway management knowledge in a clinical setting.

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Abstract

Background: The American Association of Medical Colleges deemed performing lifesaving procedures, such as airway management, a necessary medical student competency for transitioning to residency. Anesthesiology clerkships provide the unique opportunity for medical students to practice these procedures in a safe and controlled environment. We aimed to develop a checklist that assesses medical students' ability to perform the main steps of a general anesthesia induction with endotracheal intubation in the clinical setting.

Methods: We created a Checklist containing items aligned with our clerkship objectives. We modified it after receiving feedback and trialing it in the clinical setting. Medical students were evaluated with the Checklist using a pre- and post-clerkship study design: (1) in a simulation setting at the beginning of the clerkship; and (2) in the operating room at the end of the clerkship. Using paired *t*-tests, we calculated pre- and post-clerkship Checklist scores to determine curriculum efficacy. A *P* value of <.05 was determined to be statistically significant. We examined rater agreement between overall scores with intraclass correlation coefficients (ICC).

Results: Thirty medical students participated in the study. The ICC for agreement was 0.875 (95% confidence interval [CI], 0.704–0.944). The ICC for consistency was 0.897 (95% CI, 0.795–0.950). There was a statistically significant improvement in the score from baseline to final evaluation of 3.6 points (95% CI, 2.5–5.2; P = .001).

Conclusions: The statistically significant change in Checklist scores suggests that our medical students gained knowledge and experience during the introductory clerkship inducing general anesthesia and were able to demonstrate their knowledge in a clinical environment.

Keywords: Checklist, medical student education, objective assessment, anesthesiology, induction of general anesthesia with endotracheal intubation

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Figure

Figure 1. *Induction of General Anesthesia with Endotracheal Intubation Checklist. Medical students have access to a version that does not include the prompts or facilitator instructions.*

Medical Student IV Induction of General Anesthesia with Endotracheal Intubation Checklist

Student Name: _____ Period: _____
Date:_____Score:_____/20_____Evaluator:_____

2= Completed without Prompts or Neutral Prompt (What's next?); 1= Completed after One Prompt; 0=More than One Prompt/Facilitator Indicates the Next Step

Action	Prompt (Only if needed):	Score		
1. Gather and Examine Equipment a. Check for presence of mask, laryngoscope, ETT, medications	"Is there anything you want to do with your workspace?"	0	1	2
2. Monitor application and use: a. Apply BP cuff, ECG and pulse oximeter	"Is there anything you want to do that helps you to watch the patient?"	0	1	2
3. Pre-oxygenation: a. Apply mask to patient's face for at least 1 minute (ask student how long they want to do this)	"Is there anything you want to do to make the induction safer?"	0	1	2
4. Announce that the patient is ready for induction a. It is not necessary for the student to know doses, but ask about what medications they would like to give	"How should we get his patient under anesthesia"	0	1	2
5. Mask ventilation technique and measures taken to improve MV: a. Student can bag-mask ventilate either with or without an oral airway	"Is there anything you want to do before placing the ETT?"	0	1	2
6. Application of Eye protection: *a. Can be done either directly after administration of anesthetic drugs or before intubation*	"Is there anything you want to do to project areas from injuries before intubation?"	0	1	2
7. Laryngoscopy and Intubation	"It has been about 3 minutes since you started ventilating the patient"	0	1	2
8. Confirmation of adequate ETT position a. Student should check presence of ETCO2 and auscultate to ensure proper ETT position	"Is there anything you can do to see if you were successful?"	0	1	2
9. Secure the ETT	"Is there anything you would like to do the endotracheal tube?"	0	1	2
10. Initiation of mechanical ventilation: a. May be done immediately after confirmation of ETT placement	"Is there anything you can do that can help you keep this patient oxygenated?"	0	1	2
Total Points:				

Facilitator's Instructions:

A neutral prompt can be used to move the medical student forward: "What is the next step?" If a student cannot remember the next step OR if the student is about to skip a step, the facilitator should read the appropriate prompt ONCE. If the student carries out the appropriate task or says what the next step is after the prompt, 1 point is given. If the student proceeds to the incorrect next step, the facilitator will direct the student to appropriate next step or give a prompt of their choice and 0 points are given.

The facilitator/faculty member should debrief with the medical student afterwards.

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Tables

Table 1. *Checklist and Alignment With Clerkship Objectives and Undergraduate Medical Education Competency Domains*

Checklist Action	Undergraduate Medical Education Competency Domains[1]	Instructional Objective
Gather and check equipment and medications	• Application of Scientific Knowledge and Method • Clinical Information Management	Ensure patient safety by checking equipment and preparing for a smooth induction of general anesthesia with endotracheal placement.
Monitor application and use, pre-oxygenation, & application of eye protection	• Application of Scientific Knowledge and Method • Clinical Intervention • Clinical Procedures	Decide which monitors are necessary and why. Understand what pre-oxygenation is and why it is performed. Describe the function and importance of each monitor, properly apply them, and interpret their results.
Mask ventilation and apply measures taken to optimize mask ventilation	• Application of Scientific Knowledge and Method • Clinical Intervention • Clinical Procedure	Recognize challenges to effective mask ventilation and strategies to mitigate this.
Laryngoscopy & Intubation	• Application of Scientific Knowledge and Method • Clinical Procedure	Improve basic airway management skills.
Initiation of mechanical ventilation and maintenance of anesthesia	• Application of Scientific Knowledge and Method • Clinical Procedure	Apply knowledge of mechanical ventilator settings and different techniques to maintain anesthesia.

Table 2. *Individual Levels of Agreement for Each Checklist Item*

Checklist Item	Krippendorf's Alpha (95% CI)	Weighted Kappa (95% CI)	Percent Agreement, % (95% CI)
1. Gather and examine equipment	0.81 (0.58 to 0.95)	0.78 (0.56 to 0.94)	83.3 (70.0 to 96.7)
2. Monitor application and use	0.73 (0.36 to 1.00)	0.80 (0.37 to 1.00)	90.0 (80.0 to 100.0)
3. Pre-oxygenation	0.82 (0.54 to 1.00)	0.89 (0.64 to 1.00)	90.0 (79.9 to 100.0)
4. Announcement that the patient is ready	0.65 (−0.04 to 1.00)	0.65 (0.00 to 1.00)	96.7 (90.0 to 100.0)
5. Mask ventilation	0.76 (0.55 to 0.89)	0.76 (0.60 to 0.88)	63.3 (46.7 to 80.0)
6. Application of eye protection	0.80 (0.59 to 0.94)	0.80 (0.59 to 0.94)	80.0 (63.3 to 93.3)
7. Laryngoscopy	—	—	96.7 (90.0 to 100.0)
8. Confirmation of adequate ETT position	0.71 (0.39 to 0.93)	0.70 (0.39 to 0.93)	86.7 (73.3 to 96.7)
9. Secure the ETT	1.00 (0.98 to 1.00)	0.94 (0.82 to 1.00)	96.7 (90.0 to 100.0)
10. Initiation of mechanical ventilation	0.80 (0.61 to 0.91)	0.77 (0.60 to 0.89)	70.0 (53.3 to 86.7)

Abbreviations: CI, confidence interval; ETT, endotracheal tube.

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Appendix

Appendix 1. Post-Clerkship Survey

Educational Value:

Including teaching/learning environment, clinical experiences and opportunities, assessments related to clerkship objectives

Below expectations 1; Meets expectations 2; Exceeds expectations 3

Teaching:

By attending physicians, residents, fellows, other health professionals and staff

Below expectations 1; Meets expectations 2; Exceeds expectations 3

Experiences as a health care team member:

Work with health care team; Felt like a member of the team.

Below expectations 1; Meets expectations 2; Exceeds expectations 3

Please explain or give examples to support areas rated "below expectations." Please provide suggestion for improvements (eg, technology, resources, support):

Describe the strength(s) of this clerkship/rotation (eg, technology, resources, support):

Would recommend this site (for this clerkship) for others?

Probably not 1; Likely 2; Definitely 3

Anesthesiology Clerkship-specific Evaluation Questions:

1. The airway workshop and simulation experience is helpful.
    a. Disagree with this statement Neutral Agree with this statement
2. Working directly with mentors is a worthwhile experience.
    a. Disagree with this statement Neutral Agree with this statement
3. I had opportunities to perform procedures.
    a. Disagree with this statement Neutral Agree with this statement
4. I feel more comfortable managing an induction of anesthesia with endotracheal tube placement.
    a. Disagree with this statement Neutral Agree with this statement
5. The clinical skills (intubations, mask ventilation, PIV placement etc.) learned are applicable to all fields.
    a. Disagree with this statement Neutral Agree with this statement
6. The knowledge (preoperative assessment, monitors, airway management, etc.) gained is applicable to all fields.
    a. Disagree with this statement Neutral Agree with this statement
7. What is at least one thing you will take from this rotation and incorporate into your future practice?
    a. Type in answer
8. How will you incorporate this change into your future practice?
    a. Type in answer