Enhancing knowledge of head and neck anatomy in preclinical medical students using low fidelity simulation

Lisa A. Buckley*, M.S., Simulation Manager, Ross University School of Medicine
20 Franklin Blvd Apt 412, Long Beach, NY 11561, USA, 1-313-570-5176 lbuckley@rossu.edu

Rose-Claire St. Hilaire, Ph.D., Assistant Professor, Center for Teaching and Learning, Ross University School of Medicine RSt.Hilaire@rossu.edu

Gregory E. Gilbert, Ed.D., M.S.P.H., PStat®, Biostatistician, Learning Sciences, Adtalem Global Education
Adjunct Assistant Professor, Center for Teaching and Learning, Ross University School of Medicine ggilbert@rossu.edu

Kim Leighton, Ph.D., Assistant Dean Research & Simulation Faculty Development, Learning Sciences, Adtalem Global Education kleighton@devrygroup.com

Mallikarjuna Barremkala, MBBS, Assistant Professor, Department of Biomedical Sciences, Oakland University William Beaumont School of Medicine Barremkala@oakland.edu

Diana Callender, MBBS, DM, Professor & Director of the Clinical Skills and Simulation Center, Department of Clinical Sciences, Geisinger Commonwealth School of Medicine dcallender@som.geisinger.edu

David Pederson, M.S., Associate Dean Undergraduate Medical Education, Ross University School of Medicine DPederson@devrygroup.com

*Corresponding author

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What this paper adds: This paper lends support to ensuring the educational intervention matches the assessment when combining simulation with lecture to impact first year medical student learning.

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Declarations

Ethic approval and consent to participate: This project was approved by the Ross University School of Medicine Institutaional Review Board. Contact: Dr. Sean Reid, SeanReid@RossU.edu

Consent for publication: All authors have had a chance to review the manuscript and give consent before this submission for publication. This manuscript has been reviewed by the DeVry Compliance Department and has been approved for publication. This manuscript is not under consideration for publication by another journal.

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Competing interests: The authors declare they have no competing interests. None of the authors have a conflict of interest to declare. No disclaimers.

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Author contributions:
Lisa A. Buckley lead the faculty training for the simulation educational intervention, taught the students during the simulation, created data spreadsheet for analysis, wrote the background and discussion sections of the paper and provided substantial edits to the manuscript and approved the final version.

Rose-Claire St. Hilaire created data speadsheets for analysis and collected data information from the exam center. She reviewed and provided edits to the manuscript and approved the final version.

Gregory E. Gilbert analyzed all the data, wrote the methods and results sections and all tables in the manuscript. He provided substantial edits to multiple version of the manuscript and approved the final version.

Kim Leighton provided substantial edits to multiple version of the manuscript and approved the final version.

Mallikarjuna Barremkala developed anatomy questions and helped to integrate the anatomy and clinical perspective for the educational intervention and taught the students during the anatomy lecture, anatomy lab and simulation educational intervention. He reviwed and approved the final manuscript.

Diana Callender-developed the simulation educational intervention, assisted with the faculty development sessions, taught the students during the simulation edicational intervention and edited and approved the final menuscript.

David Pederson developed the simulation educational intervention, lead the faculty training for the simulation, taught the students during the simulation and reviewed and approved of the final manuscript.

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Abstract

Background: Simulation-based medical education is more prevalent in undergraduate preclinical medical education and acts as a foundation for clinical learning in years three and four. Currently, there is a call to teach clinical application of basic science material in preclinical years one and two.

Methods: Two groups of students participated in this investigation; a historical control of 270 students from the 2010 matriculating class and students receiving the intervention (anatomy lecture plus airway management simulation) from the 2012 matriculating class (n=337). Descriptive statistics were calculated for demographic and academic performance variables. Unadjusted and adjusted odds of passage of mid-term and final assessment were calculated. The final assessment was defined as one correct, two correct, and all three questions correct.

Results: Adjusted odds of passage of mid-term exam for the control group were 3.9 (95% CI: 2.7-5.9), virtually unchanged from the unadjusted odds of passage. Control group results for final exam passage as defined as one correct increased from .7 to .9 when adjusted for variables (95% CI:.3-2.5). Odds of passage of final assessment, for the control group, for adjusted models for two or greater correct increased from 4.1 to 5.6 (95% CI:2.6-13.7) and from 34.1 to 44.0 (95% CI: 21.7-102.5) when three answers (or 100%) are needed for passage.

Conclusions: When passage criteria for the final exam were defined as one correct, addition of a simulation exercise to the anatomy lecture increased the rate of passage by 11% after adjusting for covariates. However, when passage criteria for the final exam was defined as two or three correct, addition of a simulation exercise to the anatomy lecture decreased the rate of passage.

Keywords: Manikins; Simulation Training; Undergraduate Medical Education; Anatomy.

Background

Simulation-based medical education (SBME) has become more prevalent in undergraduate medical education in the last fifteen years[1–3]. This increase has been fueled by the need for updated medical training models, education using standardized clinical cases, consideration of patient safety, and research supporting the educational benefits of simulation[4]. Simulation as a teaching modality allows students opportunities to apply and hone clinical skills through experiential learning, while doing so in a safe, supportive environment, without causing harm to patients[4]. The evidence for the use of SBME has been well established for the clinical years of medical education, including the third and fourth years of medical school and residency training; however, there is a lack of research supporting use of simulation in the first two years of medical education[5].

Traditionally, the first two years of medical school are dedicated to basic science education, although there has been a call to reform medical education to include clinical application of basic science material[6]. In recent years the National Board of Medical Examiners® (NBME) has been including more clinical-based questions on the United States Medical Licensing Exam® (USMLE) Step 1[7]. These questions explore students' ability to demonstrate higher degrees of integrative knowledge and logic rather than recall facts. Simulation is one way to place clinical context around basic science content, giving students an anchor for retention and future application. In 2011, the Association of American Medical Colleges reported 84% of medical schools were using simulation in the first year of medical school and 91% in the second year[8]. Despite these high percentages, there are many questions about why or how simulation can be used during the basic science years; few answers are found in the literature. Students have reported gains in clinical confidence or procedural knowledge, as well as increased comfort and competence when managing patients with altered mental status [2]. Sperling et al. reported knowledge gains were significantly higher for students participating in simulation activities than those who did not [2, 9–11].

Simulation is supported by experiential learning theory because it actively engages learners in applying knowledge to real world tasks. SBME allows learners to have a concrete experience, reflect on the experience, conceptualize the learning, and repeat the experience[12]. Experiential learning is an effective teaching methodology for knowledge and skill retention[9].

The purpose of this investigation was to examine short-term knowledge retention, as assessed by passage of mid-term and final exams, of students enrolled in a head and neck anatomy curriculum with lectures, human cadaver lab, and an integrated simulation activity compared to students enrolled in a head and neck anatomy curriculum receiving lecture and human cadaver lab only.

Methods

This study was a non-randomized educational study using historical controls as a means for evaluation of a curricular change. This investigation was approved by the Institutional Review Board of a large offshore United States medical school where this study was conducted and subscribed to the tenets of the Declaration of Helsinki. No informed consent was sought as the investigation met the criteria for waiver of informed consent.

Sample

Two groups of students were included in this investigation. The first group was a historical control of 270 students from the 2010 matriculating class at the medical school. This was the most recent group of students receiving the traditional curriculum (lecture and human cadaver lab only). The group receiving the intervention (lecture, human cadaver lab and simulation) was a group of 337 students from the 2012 matriculating classes at the same medical school.

Instruction

During semester two, students received 19 hours (14 hours of gross anatomy and 5 hours of radiographic anatomy) of head and neck anatomy lectures and 34 hours of head and neck human

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cadaveric lab. Lecture objectives for the head and neck anatomy were broader than the objectives for the simulation session. All students completed dissection of the head and neck in the gross anatomy lab.

Intervention

In addition to didactic anatomy lectures and human cadaveric lab, the intervention group participated in one 50 minute simulation session designed to reinforce learning objectives of the head and neck anatomy curriculum. The airway simulation was chosen for this purpose becuase many of the learning objectives could be addressed in one active learning session, giving the student clinical context that supported the antomy teaching. All faculty involved in simulation sessions went through a two day simulation training course which allowed the faculty to discuss and apply adult learning theories, simulation methodology and debriefing skills prior to faciliting any simulation sessions. In addition, the simulation faculty were trained in a one hour session the week before the airway simulation teaching. This training was specific to the airway simulation facilitation and occurred each semester. Faculty were instructed to facilitate the session so each student had an opportunity to participate. During training faculty reviewed relevant anatomy, associated images, clinical context, and use of airway devices. The indications and contraindications for the airway devices were reviewed and questions were answered.

The simulation session learning objectives focused on anatomy of the oral cavity, nasal cavity, larynx, and pharynx as it relates to basic airway management. The Laerdal® Airway Management Trainer and the Laerdal Airway Demonstration Model (Laerdal Medical, Stavanger, Norway) were used for the simulation session. In groups of eight, with one clinical faculty and one anatomy faculty member, students were introduced to airway management techniques and devices. Students were shown the head tilt chin lift and jaw thrust and introduced to the bag valve mask, nasopharyngeal airway, oropharyngeal airway, laryngeal mask airway, laryngeal tube (king tube), esophageal-tracheal

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tube, endotracheal tube, and laryngoscope. The basic use of these devices and their indications and contraindications were reviewed and practiced by students throughout the 50 minute period. Special emphasis was placed on anatomical spaces and landmarks used in correct placement of each device.

Independent Variables

The independent variable assessed in this investigation was the curriculum type, specifically, a lecture and human cadaver lab only versus lecture and human cadaver lab plus one 50 minute simulation session.

Dependent Variables

Assessment of learning outcomes occurred twice. The first assessment was a mid-term exam administered during week five of the fifteen week term, directly following the head and neck anatomy teaching. The second assessment was a comprehensive final exam administered at the end of the term. Assessment questions were written in USMLE style. There were three assessment questions on the mid-term exam corresponding to our study for the control and intervention groups. The mid-term examination was scored as pass/fail. A score of two or greater was defined as passing the mid-term exam. For 2010 matriculating students the final exam was composed of one question corresponding to our study. However, the 2012 matriculating class had three questions that corresponded. All questions directly mapped to the shared learning objectives for the anatomy lectures and simulation exercise. Due to the differential in final exam questions three dependent variables for exam passage were defined: correctly answering one question, correctly answering two questions, and correctly answering three questions. Questions on the mid-term and final exams were different, but similar in content and difficulty. The point biserial for the 2010 mid-term data are 0.51, 0.47 and 0.35 and the 2012 mid-term exam are 0.10, 0.08 and 0.27. The 2012 final exam point biserial are 0.05, 0.08 and 0.15. The concept tested on the 2010 final exam was about the opening in

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the vocal folds. Concepts tested on the 2012 final exam were about the pharynx, oral cavity and clinical management of an airway. Assessments were used to track differences in performance between the intervention group and historical control group. Validity and reliability of the questions (and instruments) has not been assessed. Tests were administered on paper through ParTest and scored with ParScore[13] until December 2010. Starting in January 2011, data was collected and scored using Questionmark®[14], a software for delivering assessments.

Control Variables

Many demographic and academic variables are related to medical school performance. In this investigation we used logistic regression to control for participant differences. Age at matriculation, self-identified gender, and race are known to influence academic performance in medical school and were included in preliminary models. Student academic control variables were overall undergraduate grade point ratio (uGPR), and individual MCAT scores (Biological Sciences, Physical Sciences, Verbal). A final variable we felt important to control for was whether students attended a university-sponsored medical school preparatory program. The Medical Education Review Program (MERP) is a 15-week program offered to students granted conditional acceptance to the medical school and provides students with additional academic preparation prior to medical school matriculation. For a more complete explanation of MERP, see article by Lindner et al.[15].

Analysis

Data were entered into a Microsoft Excel®[16] spreadsheet and saved in a comma-separated value (CSV) file. Means and standard errors were calculated for the lecture and human cadaver lab group (control) and the lecture and human cadaver lab plus simulation group (intervention) for quantitative variables. Categorical variable percentages and frequencies are presented. The Wilcoxon-Mann-Whitney test was used to test if quantitative variables differed significantly and a chi-square test was

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used to test for a significant difference in categorical variables. A score of two or greater was defined as passing the mid-term exam. Due to the change in number of final exam questions between 2010 and 2012, the final exam was assessed using three different variables: passage as answering one question correctly, two questions correctly, and three questions correctly. The unadjusted odds were calculated. Logistic regression was used to ascertain the odds of passage of both exams, independently, after adjustment for covariates. A model building approach using likelihood ratio testing was used to determine if variables contributed significantly to the model. A *P* value of .2 was used as criteria for inclusion in the regression model[17]. Candidate admissions variables were entered into the models and likelihood ratio testing was used to determine the most parsimonious models. As this is an educational study, an *a priori* alpha level of .10 was specified for significance testing[18]. All analyses were done using R software[19–23].

Results

Cohort Description

The average age of the cohort was 25 years (SE=2 months and 23 days). Forty-three percent (n=260) of the cohort was female with a plurality being Asian Pacific Islander (28%; n=172) followed by White Non-Hispanic (26% n=159), and unidentified race (20% n=120). The control group consisted of 44% (n=270) of the participants and the intervention group comprised 56% of the study population (n=337). Thirty-eight percent of study participants attended MERP. Further details of the study cohort can be seen in Table 1, in addition to comparisons of the control and intervention groups.

Significant differences were seen between the control and intervention groups for all variables except age, gender (reference: male), MCAT Verbal Reasoning score, and passage of the final exam when operationalized as scoring equal to one, two or three questions correct out of three (Table 1).

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A significantly greater proportion of those in the control group attended MERP vs. the intervention group (47% vs. 30%; *P* value<.0001). Because of this difference MERP participation was examined in a subanalysis as a mediating factor.

Univariate Analysis

The unadjusted odds ratio for mid-term passage was 4.1 (95% CI:1.9-8.9). The unadjusted odds ratio for final assessment passage for the control group was 4.1 (95% CI:2.8-5.9). The control group had significantly greater odds of passage of the mid-term and final assessment than students in the intervention group. Between 2010 and 2012, when the simulation session was added, the final exam changed from one question to three questions. Due to this change, final exam passage was defined three different ways for the intervention group: one question correct, two questions correct, and three questions correct.

The unadjusted odds of passage of the final exam for the control group when passage was defined as one or more correct was .7 (95% CI: .2–1.9). This can be interpreted as participants in the control group were 30% less likely to pass the final exam than were participants in the intervention group. Stated another way, study participants in the intervention group had 1.4 (95% CI: .5–5) times the odds of passing the final exam than students in the control group if exam passage was defined as one or more questions correct. However, when final exam passage was defined as two or more correct responses, study participants in the control group had 4.1 (95% CI: 1.9–8.9) times the odds of final exam passage as study participant in the intervention group. This is a significant difference in the odds of passage of the summative exam. When the criteria are raised to having to answer three (out of three) correct for passage the unadjusted odds of passage for the control group are 34.1 (95% CI: 16.4–71.3). Again, a significant difference.

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Table 1. Demographic characteristics of the study cohort, lecture group, and lecture simulation group, (n=607)

Variable		**All(n=607)**	**Lecture+Anatomy Lab(n=270)**	**Lecture+Anatomy Lab+Simulation(n=337)**	***P* value**
Age*		25(.23)	25(.36)	25(.31)	.6883
Female†		43(260)	45(121)	41(139)	.3773
Race†	Asian/Pacific Islander	28(172)	24(66)	31(106)	.0033
	Black	9(55)	10(28)	8(27)	
	Hispanic	8(46)	5(14)	9(32)	
	Native Hawaiian/Pacific Islander	9(55)	11(31)	7(24)	
	Unidentified	20(120)	25(67)	16(53)	
	White	26(159)	24(64)	60(95)	
MERP†		38(230)	47(128)	30(102)	<.0001
Undergraduate Grade Point Ratio*		2.98(.02)	2.9(.03)	3.0(.02)	.0010
MCAT Biological Sciences*		8(.07)	8(.11)	8(.08)	.0010
MCAT Physical Sciences*		8(.07)	8(.10)	8(.08)	.0055
MCAT Verbal Reasoning*		7(.08)	7(.13)	7(.11)	.1603
Mid-term Assessment Score‡		3(1)	3(1)	3(0)	<.0001
Mid-term Assessment Passage†		69(414)	52(139)	82(275)	<.0001

Variable	All(n=607)	Lecture+Anatomy Lab(n=270)	Lecture+Anatomy Lab+Simulation(n=337)	*P* value
Final Passage (%): Score of 1†	98(586)	97(256)	98(330)	.4572
Final Passage (%): Score of 2†	92(555)	97(256)	89(299)	.0002
Final Passage (%): Score of 3†	70(419)	97(256)	48(163)	<.0001

*-Mean and standard error; values standardized.

†-Percentage and frequency

‡-Median and interquartile range

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Multivariable Analysis

Likelihood ratio testing of models predicting passage of the mid-term assessment resulted in a final model with race (reference White Non-Hispanic), undergraduate grade point ratio, and participation in MERP. After adjusting for these variables, the odds of passage of the mid-term assessment for the control group were 3.9 (95% CI: 2.7–5.9), virtually unchanged from the unadjusted odds of passage with an effect size (Cohen's d) of -.75 (95% CI: -5.91–4.4; *P* value=.77). Adjustment did not change the odds of passage; the control group maintained a significantly greater odds of passage of the mid-term exam.

Significant predictors (likelihood ratio testing) of final exam passage (using two or three correct responses as criterion for passage) were age, race (reference: White Non-Hispanic), undergraduate grade point ratio, and participation in MERP. Results can be seen in Table 2. Results for final exam passage as defined as one or greater correct were slightly increased from .7 to .9 with an effect size (Cohen's d) of -.09 (95% CI: -14.52–14.33; *P* value=.99); however, this result did not reach statistical significance. Adjusted models for both additional models (two and three correct) increased the odds substantially from 4.1 to 5.6 with an effect size (Cohen's d) of .93 (95% CI: 10.23–12.1; *P* value=.87) when two answers correct are considered for passage and from 34.1 to 44.0 with an effect size (Cohen's d) of 2.11 (95% CI: -8.57–12.78; *P* value=.70) when three answers (or 100%) are needed for passage. Both results are significantly greater odds of passing the final exam as compared to the intervention group.

Table 2. Odds of final exam passage (95% confidence intervals) and regression coefficients (standard errors) for the students in the historical control group (no simulation)

Final Exam	**Odds Ratio (95% CI)**				
Passage Criteria	**Unadjusted**	**Adjusted***	**□□**	**SE(□)***	***P* value**

1 question correct	.7 (.2–1.9)	.9 (.3–2.5)	-.2	.54	.7570
2 questions correct	4.1 (1.9–8.9)	5.6 (2.6–13.7)	1.7	.42	<.0001
3 questions correct	34.1 (16.4–71.3)	44.0 (21.7–102.5)	3.8	.39	<.0001

*- model adjusted for age, race (reference: White, Non-Hispanic), undergraduate grade point ratio, and participation in MERP

MERP Subset Analysis

Descriptive statistics comparing MERP students with those not attending MERP can be seen in Table A1. There were significant differences in undergraduate grade point ratio (*P* value<.0001), MCAT Physical Sciences score (*P* value<.0001), MCAT Biological Sciences score (*P* value<.0001), final exam score (*P* value=.0005), and final exam passage proportions when passage was defined as scoring three correct (*P* value=.0433). Table A2, displays the odds of exam passage (95% confidence intervals), regression coefficients (standard errors), and effect sizes for the students in MERP. Odds of passing the mid-term exam increase from .8 in the unadjusted model to 1.2 in the adjusted model; however, neither odds ratio is significant. The odds of passing the final exam for MERP students increased moderately for the adjusted model; however, again, neither odds ratio is significant. When final exam passage is defined as a score of three (of three) correct the odds of passage for MERP students decreases from 1.5 to 1.2. However, neither of these odds ratios are significant. Effect sizes (Cohen's d) for all odds ratios were small and not significant.

Discussion

The results of this study suggest students in the control group were 30% less likely to pass the final exam when passage was defined as equal to one question correct. When the definition for passing was two or greater (>67%), the control group was 5.6 times more likely to pass and when defined as three (100%) questions correct, the control group was 44 times the odds of passage as those in the intervention group.

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Why did the intervention group perform worse than the control group when passage was defined as two or three questions correct? One explanation may be that the assessment questions didn't accurately assess students who mastered the material from those who did not. This is evident in the point biserial for the assessment questions in both groups. Ensuring that the assessment matches the teaching is an important componenet in implementing a new teaching methodology, one that may have been overlooked in our process. Additionally, the benefits of the simulation session may have been dimished from the time of the intervention to the time of the assessment.

Our results were different from the results of Hall et al. (2015), who showed the addition of one simulation session to a traditional lecture curriculum enhanced knowledge. Our study also diagrees with the findings of Heitz, Brown, Johnson and Fich (2009) where retention of basic science knowledge was enhanced through addition of a clinical component. This further supports the possibility that in this study the questions used on the exams were not asking the questions needed to adequately assess learning outcomes.

This study has several limitations. The first limitation was the quasi-experimental design because we could not control for age, race, gender, or MERP participation. However, we controlled for significant academic performance factors. Another limitation of this study was that the summative exam questions did not test the same concept or use the same number of questions for the control and study groups. The questions were written by the anatomy faculty for the control group. The questions for the intervention group were written by the same anatomy faculty member as the control group with additional input from the clinical faculty participating in simulation. Further, although we would have preferred to have the same number of questions to determine passage, statistical methods were used to overcome this limitation. An additional potential limitation could be the difference in facilitators teaching each small group intervention session. We tried to control for this by training all simulation faculty using the same trainer in a one-hour training session approximately one week prior to the simulation. Faculty also underwent a peer review process, requiring observation and feedback in order to standardize the sessions.

Conclusions

It is important for students to learn basic science material and apply it to the clinical context to become competent physicians[6, 24]. The combination of simulation with the anatomy lecture for first year medical students in our study did not have a significant impact on the students' exam scores. This investigation acts as an example of a study evaluating the student learning outcomes as a result of a curricular intervention. More research is needed to ensure the efforts required to add simulation to a curriculum are having a significant impact on student learning outcomes if simulation is be used as an effective adjunctive teaching methodology in preclinical medical school education.

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Figure Title and Legend

Table 1. Demographic characteristics of the study cohort, lecture group, and lecture simulation group.

Table 2. Odds of final exam passage (95% confidence intervals) and regression coefficients (standard errors) for the students in the historical control group (no simulation).

Table A1. MERP Subset Analysis Tables: Demographic characteristics of the students participating and those students not participating in the Medical Education Review Program (MERP), Ross University School of Medicine, Dominica 2010 and 2012.

Table A2. Odds of exam passage (95% confidence intervals) and regression coefficients (standard errors) for the students in MERP.

APPENDIX A

MERP Subset Analysis Tables

Table A1. Demographic characteristics of the students participating and those students not participating in the Medical Education Review Program (MERP), Ross University School of Medicine, Dominica 2010 and 2012 (n=607)

Variable		MERP(n=230)	No MERP(n=377)	*P* Value
Age*		25(.21)	25(.35)	.2232
Female†		40(91)	45(169)	.2037
Race†	Asian/Pacific Islander	25(57)	31(115)	.0674
	Black	10(23)	8(32)	
	Hispanic	6(14)	8(32)	
	Native Hawaiian/Pacific Islander	12(27)	7(28)	
	Unidentified	24(55)	17(65)	
	White	23(54)	28(105)	
Lecture†		56(128)	38(142)	<.0001
Lecture+Simulation†		44(102)	62(235)	
Undergraduate Grade Point Ratio*		2.7(.03)	3.1(.02)	<.0001
MCAT Biological Sciences*		8(.12)	9(.08)	<.0001
MCAT Physical Sciences*		7(.11)	8(.08)	<.0001
MCAT Verbal Reasoning*		7(.13)	7(.10)	.1059
Mid-term Exam Score‡		3(1)	3(1)	.1226
Mid-term Exam Passage†		65(149)	71(265)	.1186
Final Exam Score‡		2(1)	2(2)	.0005

Final Exam Passage: Score of 1†	97(221)	98(365)	.4804
Final Exam Passage: Score of 2†	93(213)	92(342)	.4383
Final Exam Passage: Score of 3†	75(170)	67(249)	.0433

*-Mean and standard error
†-Percentage and frequency
‡-Median and interquartile range

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Table A2. Odds of exam passage (95% confidence intervals) and regression coefficients (standard errors) for the students in MERP

	Odds Ratio (95% CI)						
Exam	**Unadjusted**	**Adjusted**	□	**SE(□)**	***P* Value**	**Effect Size***	***P* Value**
Mid-term Exam†	.8(.5–1.1)	1.2(.8–1.9)	.2	.23	.3742	.11(-5.95–6.17)	.97
Final Exam‡ 1 correct	.7(.2–1.9)	.8(.2–2.8)	-.2	.61	.7189	-.12(-16.52–16.27)	.99
Final Exam‡ 2 correct	1.3(.7–2.4)	1.8(.9–3.9)	.6	.38	.1233	.32(-9.86–10.51)	.95
Final Exam‡ 3 correct	1.5(1.0–2.1)	1.2(.7–2.0)	.2	.25	.4499	.11(-6.62–6.83)	.98

*-Cohen's d

†-model adjusted for intervention (reference: Lecture+Simulation), race (reference: White, Non-Hispanic), and undergraduate grade point ratio

‡-model adjusted for (reference: Lecture+Simulation), age, race (reference: White, Non-Hispanic), and undergraduate grade point ratio

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