Using Simulation Modeling Approach to Predict USMLE Steps 1 and 2 Performances

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ABSTRACT

The prediction models for the United States Medical Licensure Examination (USMLE) Steps 1 and 2 performances were constructed by the Monte Carlo simulation modeling approach via linear regression. The purpose of this study was to build the robust simulation models to accurately identify the most important predictors and yield the valid range estimations of the Steps 1 and 2 scores. The application of simulation modeling approach was deemed an effective way in predicting student performances on licensure examinations. Also, sensitivity analysis (a/k/a what-if analysis) in the simulation models was used to predict the magnitudes of Steps 1 and 2 affected by changes in the National Board of Medical Examiners (NBME) Basic Science Subject Board scores. In addition, the study results indicated that the Medical College Admission Test (MCAT) Verbal Reasoning score and Step 1 score were significant predictors of the Step 2 performance. Hence, institutions could screen qualified student applicants for interviews and document the effectiveness of basic science education program based on the simulation results.

Keywords: Prediction Model, Sensitivity Analysis, Simulation Method, USMLE

1. INTRODUCTION

Numerous studies utilized analytical tools to build prediction models for licensure examination performances. Among the influential factors on the USMLE Step 1, medical school student performances such as basic science disciplines and National Board of Medical Examiners (NBME) Basic Science Subject Board scores during the first two years were considered, followed by pre-admission variables such as undergraduate grade point average (GPA) and Medical College Admission Test (MCAT) scores. Also, among the influential factors on the USMLE Step 2, the USMLE Step 1 score, NBME Basic Science Subject Board scores were considered to be the most important contributors. The statistical technique least-squares regression proved to be the most effective method for choosing significant predictors. However, the sophisticated simulation model was underutilized due to the unavailability of a user-friendly software package along with the lack of verification and validation processes in simulation.

In this study, the Monte Carlo simulation model via linear regression technique was implemented in constructing the prediction model for medical licensure examination performances. The model was employed to investigate the following research questions frequently asked by faculty and administrators: "How well can the USMLE Step 1 score be predicted by independent variables such as gender, ethnicity, undergraduate GPA, MCAT scores, and NBME Basic Science Subject Board scores?" and "How well can the USMLE Step 2 score be predicted by independent variables such as gender, ethnicity, undergraduate GPA, MCAT scores, USMLE Step 1 score, and NBME Basic Science Subject Board scores?"

The objective of this study was to construct a simulation model via linear regression: (1) to identify a subset of important explanatory variables contributing to the USMLE Steps 1 and 2 scores; (2) to derive the magnitude effect (sensitivity ratio) of individual explanatory variables on the USMLE Steps 1 and 2 scores; and (3) to compare sensitivity ratios in simulation models to slopes in linear regression models in order to demonstrate the model robustness. The simulation modeling is becoming the preferable stochastic process involving the randomization to produce probability distributions regarding input and output variables. The model's output variable can deliver more information (range/percentile estimation) than the deterministic model that yields only point estimation [1]. Therefore, this model may be an effective tool to predict student learning outcomes.

2. LITERATURE REVIEWS

Since the early 1990s medical students in the United States have been required to pass the USMLE Steps 1 and 2 for progression to sophomore or junior levels in pursuit of a clinical sciences education. The USMLE Steps 1 and 2 performances provide useful information regarding the knowledge and skills possessed by medical students, and when properly used, they are important indicators of the quality and relevance of instruction received [2]. The USMLE Step 1 and the USMLE Step 2, namely USMLE Step 2 Clinical Knowledge (CK) are standardized tests that measure students' critical thinking skills while reducing emphasis on recall of information [3], [4]. They also emphasize problem-solving skills in the integration of basic and clinical science disciplines. Therefore, the USMLE Steps 1 and 2 have

become important standard outcome measurements for effective medical education.

Passing the USMLE Step 1 is an important step in the medical licensing process, which leads to medical students being eligible to take subsequent examinations, Steps 2 and 3. The Step 1 test score is widely used as a criterion for estimating the predictive validity of the Medical College Admission Test (MCAT) and undergraduate grade point average (GPA) that are traditionally used to screen medical school applicants for an admission interview [5], [6]. Because of the significant value for improving medical education program and admission processes, there have been numerous studies investigating predictors of student performance on the USMLE Step 1 and utilizing modeling techniques to build the prediction models for licensure examination [7-12].

Among the influencing factors on the USMLE Step 1, student performance in the first two years of medical school is considered the most prominent. The pre-admission variables such as undergraduate GPA and MCAT scores are usually the two commonly used factors for building the prediction models [8, 9]. However, one study showed a strong correlation between medical gross anatomy class rank and score with both the scores on USMLE Step 1 and passing that exam, indicating that this subject should be added to the traditional predictors of medical school performance [10].

The vast majority of research studies were able to construct and interpret the functional relationship between various predictors and student performance on Step 1. The extent to which MCAT scores predict USMLE Step 1 performance was examined. The study results demonstrated that the MCAT was more strongly related to USMLE Step 1 than the undergraduate GPA [11]. MCAT scores among 112 medical schools provided better predictions of the USMLE Step 1 performance than undergraduate information alone [4]. Thus, MCAT scores should continue to have substantial utility in the admission process, particularly in screening applicants to be interviewed. In addition, the average MCAT score increase by one point led to a 7.62 point increase in USMLE Step 1 score [12]. Examining the extent to which performance on the NBME Comprehensive Basic Science Self-Assessment, a study provided more accurate basis for predicting USMLE Step 1 performance than NBME Basic Science Subject Board Tests [13-16].

Medical students in the United States are required to pass the USMLE Step 2 to be placed in a residency program. Previous studies focused on academic variables that were successful in predicting the USMLE Step 2 score. Variables having positive associations with the USMLE Step 2 score included Basic Science GPA, MCAT Biological Science score, and race [17]. Medical school performances in the first three years, the USMLE Step 1 score, and the NBME Comprehensive Clinical Science Assessment (CCSSA) scores [13, 18] were also strong indicators for predicting Step 2 performance. In addition, a positive linear relationship was evident between the USMLE Step 2 score and both Family Medicine and Clinical Evaluation scores [5, 13].

Various statistical techniques such as Pearson's correlation coefficient, t test, and ANOVA were commonly used to detect significant variables affecting the USMLE Steps 1 and 2 scores [17]. Although simple and multiple regression analyses seemed to be the preferred techniques in performing the prediction tasks [5, 13, 17], artificial intelligence models such as Generalized Regression Neural Network (GRNN), and the multi-layered Feed Forward Neural Network (FFNN) were the most sophisticated modeling approaches to discern the pattern related to the USMLE Step 2 performances [17].

The simulation model is a sophisticated modeling tool for quantifying the relative contribution of the uncertain input (independent) variables to the overall variance and range of output (dependent) variable. This process approximates the output variable through a random sampling algorithm. The use of simulation technology in medical education has significantly increased during the past decade. The finding of a simulation method confirmed that "learning or mastery of skills actually occurs" based on simulation results [18]. Although medical schools and related healthcare facilities have used this technique to evaluate medical competencies across various domains such as patient care, medical knowledge, practice-based learning, communication skills, and professionalism [19], using simulation models to predict medical licensure examination is still underutilized. To our best knowledge, this paper generated the first simulation model in predicting medical student licensure examination performances.

3. METHODOLOGY

The simulation process can be performed by using IBM SPSS simulation software with a maximal sample size of 100,000 simulation runs. During this process, samples are randomly selected with the parameters of specific probability distributions as well as their correlations.

In the simulation model, the correlation coefficients between individual explanatory variables and the USMLE Steps 1 and 2 scores were displayed through the tornado chart. The explanatory variables were ranked in descending order based on the absolute value of the correlation coefficients. In another tornado chart, the change in the USMLE Steps 1 and 2 scores for plus or minus one standard deviation change in explanatory variables showed the sensitivity ratios of the USMLE Steps 1 and 2 scores.

Sensitivity analysis was also performed by identifying the most important explanatory variables in the model. The explanatory variables with the greatest impact on the USMLE Steps 1 and 2 scores were considered the key explanatory variables. Sensitivity analysis was used to vary the model results under plausible values of parameter change on a key explanatory variable holding others constant. This analysis was applied because it could enhance the understanding of the USMLE Steps 1 and 2 performances through its linkages with explanatory variables. It is anticipated that the study results could determine the consistency of the slopes in linear regression and the sensitivity ratios in the sensitivity analysis. Therefore, the simulation model via linear regression could provide the College's decision-makers with the evidence-based information leading to effective intervention strategies.

Medical students with the complete records available in matriculation years 2010-2013 (n=313 for Step 1 prediction and n=196 for Step 2 prediction) were selected for data analysis using linear regression. Also, a random selection of 1,000 simulation run (stochastic process) was executed to form another sample chosen for independent sample and equal probability in the simulation models.

4. STUDY VARIABLES

The purpose of this study was to assess whether prediction models based on the MCAT scores, and student performances on all required NBME Basic Science Subject Board courses in the medical school curriculum could accurately predict performances of USMLE Steps 1 and 2. The outcome variables for this study were the USMLE Steps 1 and 2 first-time taker scores. Fifteen variables were treated as independent variables for the USMLE Step 1--gender (1-male; 0-female), ethnicity (1-African American; 0-Non-African American), undergraduate GPA, MCAT scores (Biological Sciences, Physical Sciences, and Verbal Reasoning), and NBME Basic Science Subject Board scores (Anatomy, Biochemistry, Microbiology, Pathology, Pharmacology, and Physiology). As shown in Table I, sixteen variables were considered as independent variables for the USMLE Step 2, which included the USMLE Step 1 score and fifteen variables mentioned above.

TABLE I
STUDY VARIABLES

Variable Names	Variable Descriptions
RACE_GRP	Race Group (1- African American; 0 - Non-African American)
GENDER_GRP	Gender Group (1- Male; 0 - Female)
BS_GPA	Undergraduate Science GPA
UG_GPA	Undergraduate GPA
MCAT_VR	MCAT Verbal Reasoning Score
MCAT_PS	MCAT Physical Science Score
MCAT_BS	MCAT Biological Science Score
AnatEmbry	NBME Anatomy and Embryology Subject Board Score
Biochemistry	NBME Biochemistry Subject Board Score
Microbiology	NBME Microbiology Subject Board Score
Pathology	NBME Pathology Subject Board Score
Pharmacology	NBME Pharmacology Subject Board Score
Physiology	NBME Physiology Subject Board Score
Comp_BS_Jan	NBME Comprehensive Subject Board Score from January Examination
Comp_BS_Apr	NBME Comprehensive Subject Board Score from April Examination
Step1_Score	USMLE Step 1 Score

5. STUDY RESULTS

USMLE Step 1 Prediction Results: The study attempted to find the association between USMLE Step 1 performance and its predictors under the investigation. Of the fifteen predictors used in the model, the NBME Anatomy/Embryology and Pathology Subject Board scores were positively and significantly associated with the USMLE Step 1 performance with p value less than the .01 significance level. Also, the NBME Pharmacology score positively and significantly contributed to the USMLE Step 1 performance with p value less than the .05 significance level. The NBME Comprehensive Basic Science Subject Board Score from April examination positively and significantly impacted the Step 1 performance with p value less than the .001 significance level. However, the following variables had no effect on the USMLE Step 1 performance: race; gender; basic science GPA; undergraduate GPA; MCAT Verbal Reasoning, Physical Science, and Biological Science Scores; and NBME Basic Science Subject Board Scores in Biochemistry, Microbiology, Physiology, and Comprehensive Basic Science Subject Board from January examination.

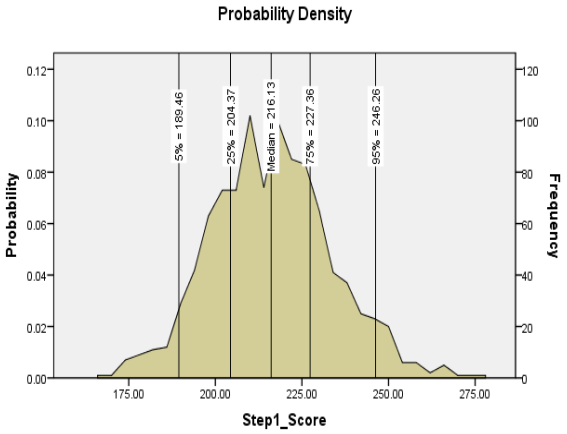
TABLE II
LINEAR REGRESSION FOR USMLE STEP 1

Variables in Equation	Unstandardized Coefficients (β or Slope)	Standardized Coefficients (Beta)	P Value
RACE_GRP	3.559	.070	.052
GENDER_GRP	.087	.002	.961
BS_GPA	-2.104	.041	.605
UG_GPA	1.392	.021	.784
MCAT_VR	-.163	.013	.677
MCAT_PS	.030	.002	.947
MCAT_BS	.010	-.001	.985
Anatomy and Embryology	.240	.107	.007**
Biochemistry	.153	.075	.079
Microbiology	.216	.087	.062
Pathology	.184	.127	.002**
Pharmacology	.156	.092	.035*
Physiology	.109	.057	.278
Comp_BS_Jan	.056	.021	.676
Comp_BS_Apr	1.035	.506	.000***

* $p < .05$, ** $p < .01$, and *** $p < 0.001$

The data analysis was first performed by displaying the probability distributions and related parameters of input variables. The probability distributions consisted of normal distributions for three NBME Basic Science Subject Board scores (Anatomy and Embryology, Biochemistry, Microbiology) and MCAT Verbal Reasoning; three lognormal distributions for the NBME Basic Science Subject Board Pathology score, MCAT Physical Science score, and Undergraduate GPA; two gamma distributions for NBME Basic Science Subject Board Pharmacology, and Physiology scores; and two triangular distributions for gender and race groups.

Range Estimations of USMLE Step 1: As shown in Fig. 1 below, median (50th percentile) of all students had a USMLE Step 1 score equal to 216.13. Also, 25% of all students had USMLE Step 1 score over 204.37, and only 5% of all students had USMLE Step 1 score greater than 246.26.



< 189.46	189.46 - 246.26	> 246.26
5%	90%	5%

Fig. 1 Probability Density Function for USMLE Step 1

Variables Importance for USMLE Step 1: As shown in Fig. 2, the NBME Comprehensive Basic Science Subject Board score from April administration was the highest correlated explanatory variable that contributed to the USMLE Step 1 score (r = 0.95), followed by the NBME Physiology Subject Board score (r = 0.82) and the NBME Comprehensive Basic Science Subject Board score from January exam (r = 0.78).

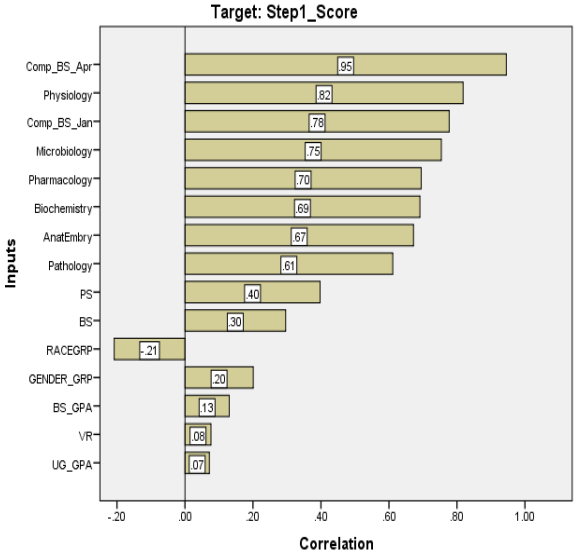
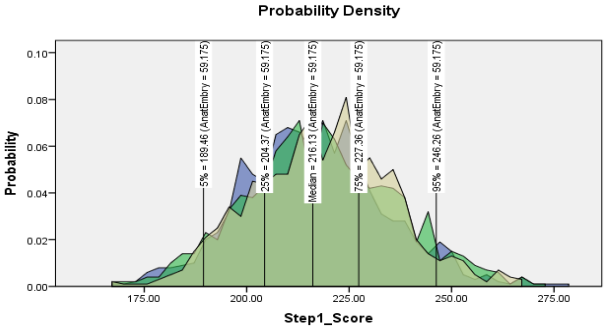


Fig. 2 Tornado Chart for Correlations with USMLE Step 1

Sensitivity Analysis for USMLE Step 1 Score: The study results showed that if the NBME Anatomy/Embryology score increased by five points (from 59.175 to 64.175), the USMLE Step 1 score would increase by two points (from 216.364 to 218.213). However, additional five-point increments (from 64.175 to 69.175) of the NBME Anatomy/Embryology score would only result in a slight increase of less than one point (from 218.213 to 218.654).



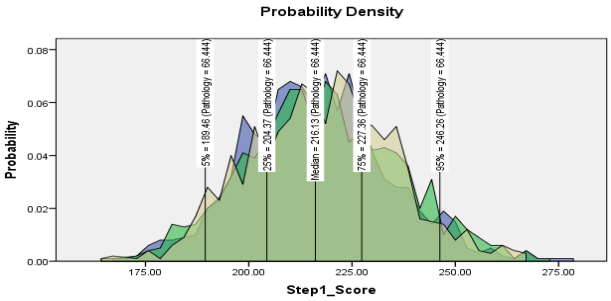
AnatEmbry: mean*	< 189.46	189.46 - 246.26	> 246.26
59.175	5%	90%	5%
64.175	6%	88%	6%
69.175	4%	91%	5%

*Sensitivity analysis based on iterations of input field: AnatEmbry. Fixed distribution parameters: stddev=9.251

Input Variable	Input Variable Changes	Outcome Changes (USMLE Step 1 Score)	95% Confidence Interval for USMLE Step 1 mean Score	
			Lower	Upper
NBME Anatomy and Embry Score	59.175	216.364	215.274	217.455
	64.175	218.213	217.073	219.354
	69.175	218.654	217.579	219.729

Fig. 3 Probability Density Function Based on the Increment of NBME Anatomy/Embryology Subject Board Score

The study results showed that if the NBME Pathology increased by five points (from 66.444 to 71.444), the USMLE Step 1 would increase by two points (from 216.364 to 217.863). However, additional five point increments (from 71.444 to 76.444) of the NBME Pathology score would only result in a slight increase.



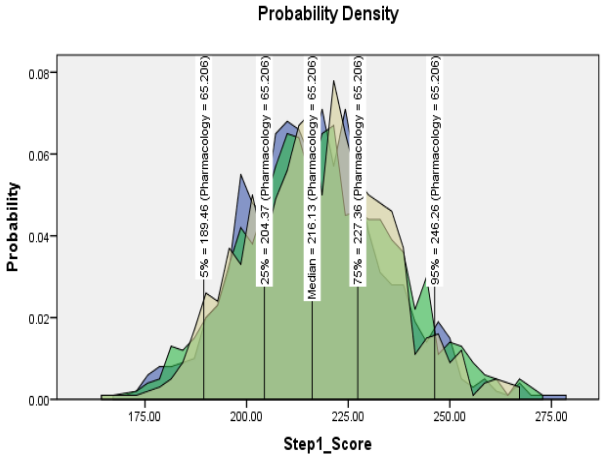
Pathology: a*	< 189.46	189.46 - 246.26	> 246.26
66.444	5%	90%	5%
71.444	6%	88%	6%
76.444	5%	90%	5%

*Sensitivity analysis based on iterations of input field: Pathology. Fixed distribution parameters: b=4.775 c=.

Input Variable	Input Variable Changes	Outcome Changes (USMLE Step 1 Score)	95% Confidence Interval for USMLE Step 1 Mean Score	
			Lower	Upper
NBME Pathology Score	66.444	216.364	215.274	217.455
	71.444	217.863	216.715	219.011
	76.444	217.943	216.852	219.033

Fig. 4 Probability Density Function Based on the Increment of NBME Pathology Subject Board Score

The study results showed that if the NBME Pharmacology score increased by five points (from 65.206 to 70.206), the USMLE Step 1 score would increase by one point (from 216.364 to 217.790). However, additional five-point increments (from 70.208 to 75.208) of the NBME Pharmacology score would only result in a slight increase of less than one point (from 217.790 to 217.807).



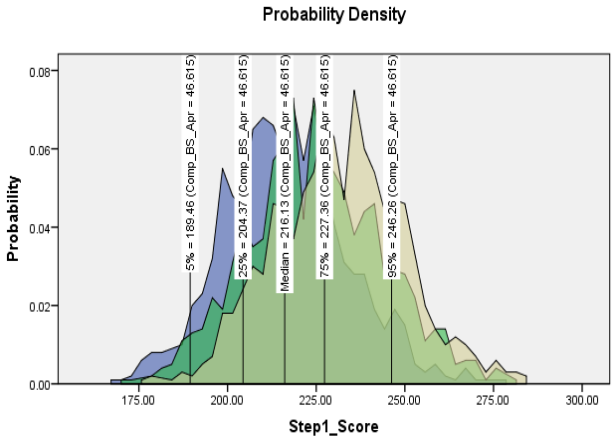
Pharmacology: mean*	< 189.46	189.46 - 246.26	> 246.26
65.206	5%	90%	5%
70.206	6%	88%	6%
75.206	5%	90%	5%

*Sensitivity analysis based on iterations of input field: Pharmacology. Fixed distribution parameters: stddev=12.219

Input Variable	Input Variable Changes	Outcome Changes (USMLE Step 1 Score)	95% Confidence Interval for USMLE Step 1 Mean Score	
			Lower	Upper
NBME Pharm Score	65.208	216.364	215.274	217.455
	70.208	217.790	216.649	218.930
	75.208	217.807	216.732	218.881

Fig. 5 Probability Density Function Based on the Increment of NBME Pharmacology Subject Board Score

The study found that if the NBME Comprehensive Basic Science score from April exam increased by five points (from 46.615 to 51.615), the USMLE Step 1 score would increase by an impressive eight points (different between 216.364 and 224.707). An additional five-point increment (from 51.615 to 56.615) of the NBME Comprehensive Basic Science score from April exam would result in another increase by six points (different between 224.707 and 231.578).



Comp_BS_Apr: shape*	< 189.46	189.46 - 246.26	> 246.26
46.615	5%	90%	5%
51.615	3%	84%	13%
56.615	1%	78%	21%

*Sensitivity analysis based on iterations of input field: Comp_BS_Apr. Fixed distribution parameters: scale=.675

Input Variable	Input Variable Changes	Outcome Changes (USMLE Step 1 Score)	95% Confidence Interval for USMLE Step 2 Mean Score	
			Lower	Upper
NBME Comp Subject Board Score (Apr)	46.615	216.364	215.274	217.455
	51.615	224.707	223.533	225.880
	56.615	231.578	230.440	232.713

Fig. 6 Probability Density Function Based on the Increment of NBME Compressive Subject Board April Examination Score

USMLE Step 2 Prediction Results: Of the sixteen predictors in the model, gender was a significant predictor for the USMLE Step 2 with p value less than the .001 significance level, indicating that male students scored 8 points less than female students. MCAT Verbal Reasoning score positively and significantly contributed to the USMLE Step 2 with p less than the .05 significance level, showing that a 2-point increment of MCAT Verbal Reasoning score led to an increase of the USMLE Step 1 by 1.2 points. The NBME Comprehensive Basic Science Subject Board scores from January examination was positively and significantly associated with the USMLE Step 1. Other significant contributor was the USMLE Step 1 score with p value less than the .001 significance level, indicating that a 10-point increase of the USMLE Step 1 contributed to a 2-point increment of the USMLE Step 2 score. However, the following variables had no effect on the USMLE Step 2: race, basic science GPA, undergraduate GPA, MCAT Physical Science and Biological Science Scores, and NBME Anatomy/Embryology, Biochemistry, Microbiology, Pathology, Pharmacology and Physiology Subject Board scores as well as NBME Comprehensive Basic Science Subject Board scores from April examination.

TABLE III
LINEAR REGRESSION FOR USMLE STEP 2

Variables in Equation	Unstandardized Coefficients (β or Slope)	Standardized Coefficients (Beta)	P Value
RACE_GRP	-3.577	-.075	.216
GENDER_GRP (M=1; F=0)	-8.126	-.226	.000***
BS_GPA	-6.875	-.158	.303
UG_GPA	11.223	.210	.169
MCAT_VR	1.246	.115	.037*
MCAT_PS	.923	-.084	.211
MCAT_BS	.379	.033	.609
AnatEmbry	.164	.083	.230
Biochemistry	-1.04	-.055	.423
Microbiology	-.032	-.013	.871
Pathology	.090	.062	.328
Pharmacology	.023	.015	.834
Physiology	.103	.064	.465
Comp_BS_Jan	.473	.202	.028*
Comp_BS_Apr	.300	.161	.161
Step1_Score	.286	.295	.001**

* p < .05, ** p < .01, and *** p < 0.001

Range Estimations of the USMLE Step 2 Score: Fig. 7 displayed the probability density function (PDF) of the USMLE Step 2 based on a 1,000 simulation runs (1,000 students randomly chosen for independent sample and equal probability). As shown in Fig. 7, median (50th percentile) of the USMLE Step 2 score was equal to 225.55.

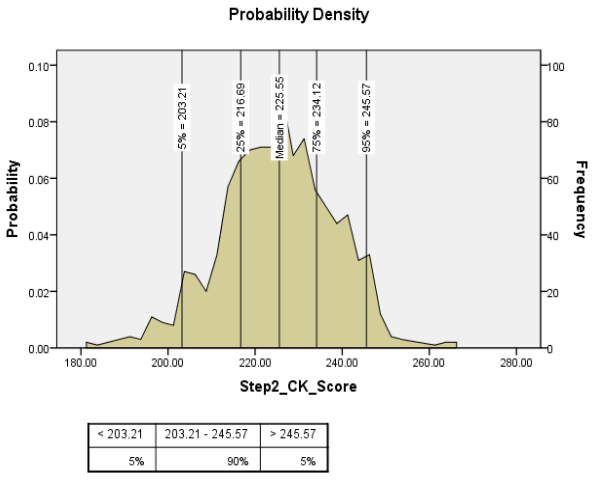


Fig. 7 Probability Density Function for USMLE Step 2

Variables Importance for USMLE Step 2: As shown in Fig. 8, the three highest explanatory variables correlated with the USMLE Step 2 were the NBME Comprehensive Basic Science Subject Board Score from April exam (r=0.88), the USMLE Step 1 (r=0.88), and the NBME Comprehensive Basic Science Subject Board Score from January exam (r=0.77).

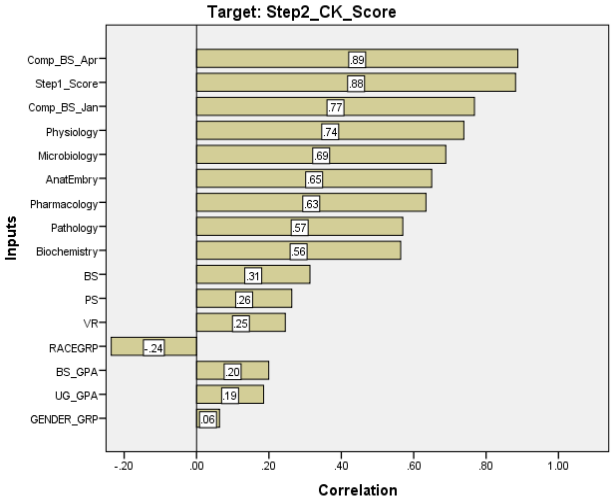
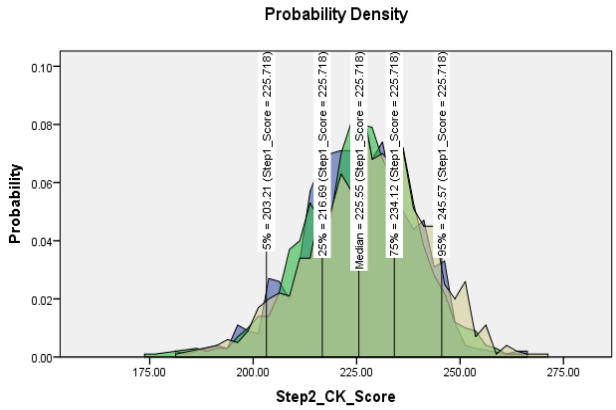


Fig. 8 Tornado Chart for Correlations with USMLE Step 2

Sensitivity Analysis for USMLE Step 2 Score: The study results showed that if the USMLE Step 1 increased by five points (from 225.718 to 230.718), the USMLE Step 2 would increase by 0.610 points (from 225.026 to 225.636). However, if the USMLE Step 1 increased an additional five points (from 230.718 to 235.718), the USMLE Step 2 would rise by two points (from 225.636 to 227.701).



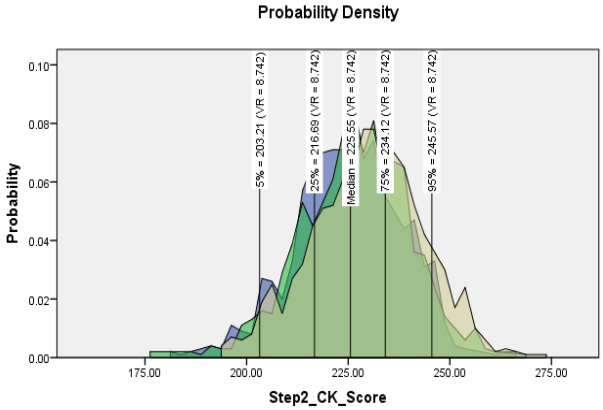
Step1_Score: a*	< 203.21	203.21 - 245.57	> 245.57
225.718	5%	90%	5%
230.718	5%	89%	5%
235.718	5%	86%	9%

*Sensitivity analysis based on iterations of input field: Step1_Score. Fixed distribution parameters: b=12.177

Input Variable	Input Variable Changes	Outcome Changes (USMLE Step 2 Score)	95% Confidence Interval for USMLE Step 2 Mean Score	
			Lower	Upper
USMLE Step 1 Score	225.718	225.026	224.213	225.840
	230.718	225.636	224.805	226.467
	235.718	227.701	226.828	228.575

Fig. 9 Probability Density Function Based on the Increment of USMLE Step 1 Score

The increment of MCAT Verbal Reasoning score also displayed an increase in the USMLE Step 2 score, which the latter score rose two points (from 225.026 to 226.570) due to a two-point increment of the former score (from 8.742 to 10.742). Another two-point increment of the MCAT Verbal Reasoning score (from 10.742 to 12.742) produced a three-point increase in the USMLE Step 2 score (from 226.570 to 229.580).



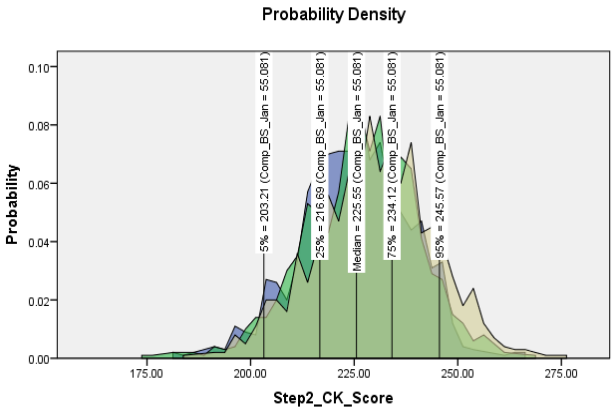
VR: a*	< 203.21	203.21 - 245.57	> 245.57
8.742	5%	90%	5%
10.742	4%	89%	7%
12.742	3%	85%	12%

*Sensitivity analysis based on iterations of input field: VR. Fixed distribution parameters: b=5.507 c=.000

Input Variable	Input Variable Changes	Outcome Changes (USMLE Step 2 Score)	95% Confidence Interval for USMLE Step 2 Mean Score	
			Lower	Upper
MCAT VR Score	8.742	225.026	224.213	225.840
	10.742	226.570	225.740	227.399
	12.742	229.580	228.708	230.453

Fig. 10 Probability Density Function Based on the Increment of MCAT Verbal Reasoning Score

The study results showed a two-point increase in USMLE mean Step 2 score (from 225.026 to 226.636) for a five-point NBME Comprehensive Subject Board score from January examination increase (from 55.081 to 60.081). An additional five-point rose in the NBME Comprehensive Subject Board score from January examination resulted in the USMLE Step 2 score increase by three points (from 226.636 to 229.741). Also, when the upper tail (with the score 245.57 as a cutoff point) of the USMLE Step 2 score distribution increased from 5% to 13% of the examination takers, eight percent of total students were more likely to achieve the highest score.



Comp_BS_Jan: a*	< 203.21	203.21 - 245.57	> 245.57
55.081	5%	90%	5%
60.081	5%	89%	7%
65.081	4%	83%	13%

*Sensitivity analysis based on iterations of input field: Comp_BS_Jan. Fixed distribution parameters: b=.138

Input Variable	Input Variable Changes	Outcome Changes (USMLE Step 2 Score)	95% Confidence Interval for USMLE Step 2 Mean Score	
			Lower	Upper
NBME Comp Subject Board Score (Jan)	55.081	225.026	224.213	225.840
	60.081	226.636	225.797	227.475
	65.081	229.741	228.849	230.633

Fig. 11 Probability Density Function Based on the Increment of NBME Comprehensive Subject Board January Examination Score

Summaries of Linear Regression and Sensitivity Analyses for USMLE Step 1: Linear regression model for the USMLE Step 1 prediction yielded the R squared value of 0.74, indicating that fifteen explanatory variables combined account for 74% of the variation in the USMLE Step 1 score. In addition, the values of tolerance greater than 2.0 proved that collinearity was not an issue while Durbin-Watson statistic of 1.94 was in the range of 1.5 and 2.5, indicating that the assumption of residual independence was not violated. Therefore, it was valid to compare the study results of linear regression analysis and those of simulation model via linear regression for the USMLE Step 1 performance.

As shown in Table IV, the predicted increase of 0.229 points in the USMLE Step 1 score could be derived from the one-point increment of the NBME Anatomy and Embryology score. A one-point increment in the NBME Comprehensive Basic Science Subject Board score from April examination could result in a 1.521 point increase in the USMLE Step 1 score. However, predicting an increase of 0.156 and 0.144 points in the USMLE Step 1 score can be attributable to the one-point increment of both the NBME Pathology and Pharmacology scores, respectively.

Linear regression analysis and simulation model via linear regression yielded consistent results for the USMLE Step 1 predictions, demonstrating the model's robustness. As shown in TABLE IV, the slope (0.240) of the NBME Anatomy and Embryology in linear regression compared to a sensitivity ratio (0.229) of the same discipline in simulation model were equivalent. The slope (0.184) of the NBME Pathology showed little variation from the sensitivity ratio (.158). Also, the slope (0.156) for the Pharmacology displayed a very close value to the sensitivity ratio (0.144.). In addition, the slope (1.035) of NBME Comprehensive Basic Science Subject Board scores in April examination exhibited somewhat close value to the sensitivity ratio (1.521).

TABLE IV
SENSITIVITY ANALYSIS FOR USMLE STEP 1

Input Variable	Input Variable Changes (10 Units Change)	Outcome Changes (USMLE Step 1 Score)	Sensitivity Ratio from Simulation Model (Per Unit Change in Input)	Slope from Linear Regr. Model (Per Unit Change in Input) from Table II
NBME Anatomy and Embry. Score	59.175	216.364	0.229	0.240
	69.175	218.654		
NBME Path. Score	66.444	216.364	0.158	0.184
	76.444	217.943		
NBME Pharm. Score	65.208	216.364	0.144	0.156
	75.208	217.807		
NBME Comp Subject Board Score (Apr)	46.615	216.364	1.521	1.035
	56.615	231.578		

Summaries of Linear Regression and Sensitivity Analyses for USMLE Step 2: Linear regression model for the USMLE Step 2 prediction yielded the R squared value of 0.53, showing that sixteen explanatory variables combined account for 53% of the variation in the USMLE Step 2. In addition, the values of tolerance greater than 2.0 proved that collinearity was not an issue while Durbin-Watson statistic of 2.08 was in the range of 1.5 and 2.5, indicating that the assumption of residual independence was not violated. Therefore, it was appropriate to compare the study results of linear regression analysis and those of simulation model via linear regression for the USMLE Step 2 performance.

As shown in Table V, the prediction of an increase of 0.286 points in the USMLE Step 2 score was attributable to the one-point increment of the USMLE Step 1 score. Surprisingly, the MCAT Verbal Reasoning score influenced the USMLE Step 2 performance. The one-point MCAT Verbal Reasoning score increment led to a 1.246 point increase in the USMLE Step 2 score (see Table V). The USMLE Step 2 score increased 0.473 point as a result of the one-point increment in the NBME Comprehensive Basic Science Subject Board Score from January examination.

Linear regression analysis and simulation model via linear regression produced consistent results for the USMLE Step 2 predictions, representing the model's robustness. As shown in TABLE V, the slope (1.246) of the MCAT Verbal Reasoning in linear regression compared to a sensitivity ratio (1.139) of the same discipline in simulation model were close to each other. The slope (0.473) of the NBME Comprehensive Subject Board score in January examination in linear regression compared to a sensitivity ratio (0.472) of the same discipline in simulation model were similar. Likewise, the slope (0.286) of the USMLE Step 1 score in linear regression showed a close value to the sensitivity ratio (0.268).

TABLE V
SENSITIVITY ANALYSIS FOR USMLE STEP 2

Input Variable	Input Variable Changes	Outcome Changes (USMLE Step 2 Score)	Sensitivity Ratio from Simulation Model (Per Unit Change in Input)	Slope from Linear Regr. Model (Per Unit Change in Input) from Table III
MCAT VR Score	8.742	225.026	1.139	1.246
	12.742	229.580		
NBME Comp Subject Board Score (Jan)	55.081	225.026	0.472	0.473
	65.081	229.741		
USMLE Step 1 Score	225.718	225.026	0.268	0.286
	235.718	227.701		

6. CONCLUSIONS

The major findings indicated that the USMLE Step 1 score was significantly affected by the NBME Anatomy and Embryology,

Pathology, Pharmacology, and Comprehensive Basic Science Subject Board score in April examination, which emerged as the most significant variables. The predictors for the USMLE Step 2 score were the MCAT Verbal Reasoning, USMLE Step 1 score, and the NBME Comprehensive Subject Board score from January examination. The NBME Subject Board scores being the predictors of USMLE Step 1 performance were consistent with prior studies in literature which confirmed the accuracy of the simulation results [12]. The contributions of the USMLE Step 1 and the NBME Comprehensive Subject Board from January examination for the USMLE Step 2 were consistent with previous studies [12, 18], indicating that the study results were valid.

This study demonstrated that the simulation modeling approach was deemed an effective way in predicting student licensure examination performances. Therefore, the prediction results could help the College build a consensus that the USMLE Step 1 performance was a significant predictor of the USMLE Step 2. In addition, the prediction model could help institutions document the effectiveness of basic science education programs because the USMLE Step 2 performance in clinical science training was attributable to the USMLE Step 1 performance in basic science education.

The USMLE Step 2 is part of a three-step complementary process used for the granting of U.S. medical licenses. The study result showed that female students had significantly higher mean score than male students when other important variables were taken into account. However, the MCAT Verbal Reasoning score as a predictor for USMLE Step 2 was not supported by the literature review. Therefore, the contribution of the MCAT Verbal Reasoning score to the USMLE Step 2 performance needs to be further investigated.

Future work involving standardized tests such as Health Science Reasoning Test (HSRT) would ensure better model fitting in predicting medical licensure examination performances. The HSRT is created specifically to measure critical thinking of health science trainees and professionals as well as predict licensure examination and clinical performances. This test is used by educational researchers and employers in various health science settings due to its capability to provide data for student learning outcome assessments [19]. In addition, the future study should examine the relationship between the Objective Structured Clinical Examinations (OSCE) and USMLE Step 2 performance since the total OSCE score is significantly associated with USMLE Step 2 [20].

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