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

Chau-Kuang Chen, John Hughes, Jr., A. Dexter Samuels

***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 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.

I. 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 scores 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 score, respectively; (2) to derive the magnitude effect (sensitivity ratio) of individual explanatory variables on the USMLE Steps 1 and 2 score, respectively; 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.

II. 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

Chau-Kuang Chen, Ed.D., Professor and Director of Institutional Research, Meharry Medical College, Tennessee USA (e-mail: ckchen@mmc.edu).
John Hughes, Jr., Computer Programmer Analyst, Office of Institutional Research, Meharry Medical College, Tennessee USA (e-mail: jhughes@mmc.edu).
A. Dexter Samuels, Ph.D., SRVP, Student Affairs & Executive Director, Robert Wood Johnson Center for Health Policy, Meharry Medical College, Tennessee USA (e-mail: dsamuels@mmc.edu).

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 programs 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]-[17].

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 [18]. Medical school performances in the first three years, the USMLE Step 1 score, and the NBME Comprehensive Clinical Science Assessment (CCSSA) scores [13], [19] were also strong indicators for predicting Step 2 performance. In addition, a positive linear relationship was evident between the USMLE Step 2 scores 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 [18]. Although simple and multiple regression analyses seemed to be the preferred techniques in performing the prediction task [5], [13], [18], artificial intelligence models such as Generalized Regression Neural Network (GRNN), and the multi-layered Feed Forward Neural Network (FRNN) were the most sophisticated modeling approaches to discern the pattern related to the USMLE Step 2 performances [18].

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 [19]. 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 [20], using simulation models to predict medical licensure examination is still underutilized. To our best knowledge, this paper generated the first simulation models in predicting medical student licensure examination performances.

III. Methodology

Meharry Medical College implemented a Centralized Institutional Research Reporting System (CIRRS) to track medical student progression during matriculation since the beginning of the 21st century. The system stores individual student profiles consisting of pre-admission variables, subject board performances, and licensure examination results. Due to the availability and accessibility of the CIRRS, institutional researchers are able to merge files and retrieve research data to build the simulation model successfully.

Implementation of a simulation model involves the following six steps: (1) quantify input and output variables; (2) specify input probability distributions and related parameters; (3) choose the simulation model via linear regression equation; (4) establish the relationships among independent variables; (5) perform simulation runs based on the identified independent variables and the correlations; and (6) conduct sensitivity analysis.

The simulation process was performed by using IBM SPSS simulation software with a large sample size of 1,000 simulation runs. During this process, samples were randomly selected with the parameters of specific probability distributions as well as its correlations.

In the simulation model, the correlation coefficients between individual explanatory variables and the USMLE Steps 1 and 2 score 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 score for plus or minus one standard deviation change in explanatory variables showed the sensitivity ratios of the USMLE Steps 1 and 2 score, respectively.

In this study, it was critical to establish the correlation among explanatory variables. Each simulation run represented the probability of occurrence of a student's USMLE Steps 1 and 2 score and related explanatory variables. The simulation

process applied constraints to the simulation runs to ensure that the random selection of the explanatory variable did not violate the specific relationship through correlation coefficients. A cumulative probability distribution of all the simulation runs was plotted and used to assess the probability for the USMLE Steps 1 and 2 above or below a specific value, respectively.

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 score were considered the key explanatory variables. Sensitivity analysis was used to vary the model results under plausible values of parameter changes. If the conclusions continued to hold under varied conditions, then the model was considered to be valid.

IV. 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 performance of USMLE Steps 1 and 2, respectively. The outcome variables for this study were the scores on the USMLE Steps 1 and 2 first-time taker scores. Twelve 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). Thirteen variables were considered as independent variables for the USMLE Step 2, which included the USMLE Step 1 score and the 12 variables mentioned above (see Table I).

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
VR	MCAT Verbal Reasoning Score
PS	MCAT Physical Science Score
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

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 linear regression analyses. Linear regression models were constructed to identify significant predictors for Steps 1 and 2 performances. Also, a random selection of 1,000 simulation run (stochastic process) was executed to form a study sample chosen for independent sample and equal probability in the simulation models. The simulation modeling approach was implemented to predict the magnitudes of Steps 1 and 2 affected by changes in crucial predictors and ultimately, determine the consistency of the slopes in linear regression and the sensitivity ratios in the simulation model. All analyses were performed using IBM SPSS Version 24.

V. Study Results

A. USMLE Step 1 Prediction Results

Linear regression model yielded the R squared value of 0.74, indicating that fifteen explanatory variables combined (See Table II) account for 74% of the variance in the USMLE Step 1 score. Also, 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.

The study discovered an association between USMLE Step 1 performance and predictors under the investigation. Of the 15 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 the 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 the January examination.

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.

B. Range Estimations of USMLE Step 1

As shown in Fig. 1, 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.

C. 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 administration (r = 0.78).

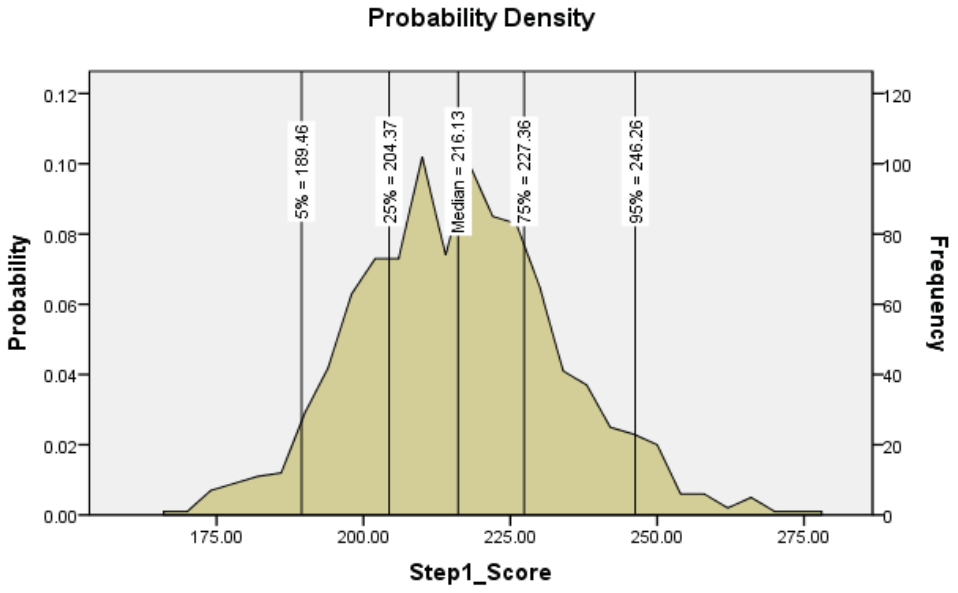
D. Sensitivity Analysis for USMLE Step 1 Score

The study results showed that the percentage of the USMLE Step 1 score in the interval being less than 189.46 decreased from 5% to 4% if the NBME Anatomy/Embryology score increased by 10 points (from 59.175 to 69.175). Meanwhile, the percentage of the USMLE Step 1 score in the interval of 189.46 - 246.26 increased from 90% to 91%, meaning that a five-point increment in the NBME Anatomy/Embryology score had an effect on the USMLE Step 1 performance. Therefore, the NBME Anatomy/Embryology score had very little effect on the USMLE Step 1 performance. Also, 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).

TABLE II
LINEAR REGRESSION FOR USMLE STEP 1

Variables in Equation	Unstandardized Coefficients (β or Slope)	Standardized Coefficients (Beta)	P Value
(Constant)	77.881		.000
RACE_GRP	3.559	.070	.052
GENDER_GRP	.087	.002	.961
BS_GPA	-2.104	.041	.605
UG_GPA	1.392	.021	.784
VR	-.163	.013	.677
PS	.030	.002	.947
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



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

Fig. 1 Probability Density Function for USMLE Step 1

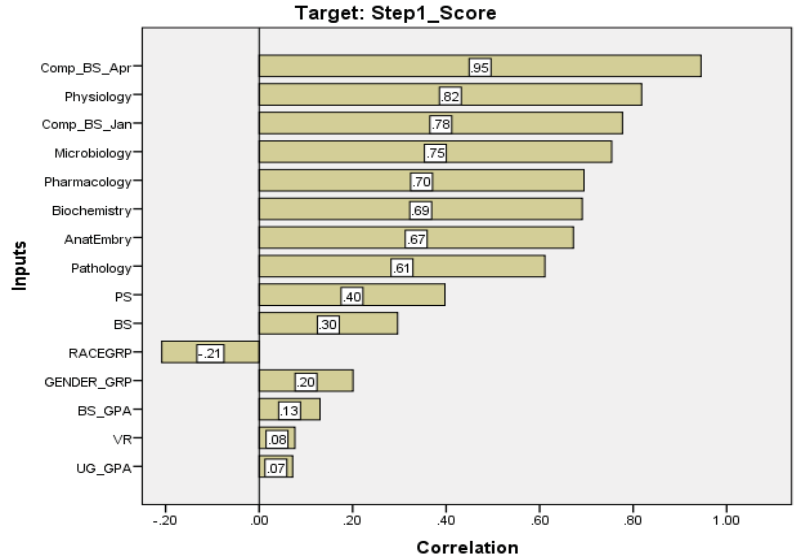
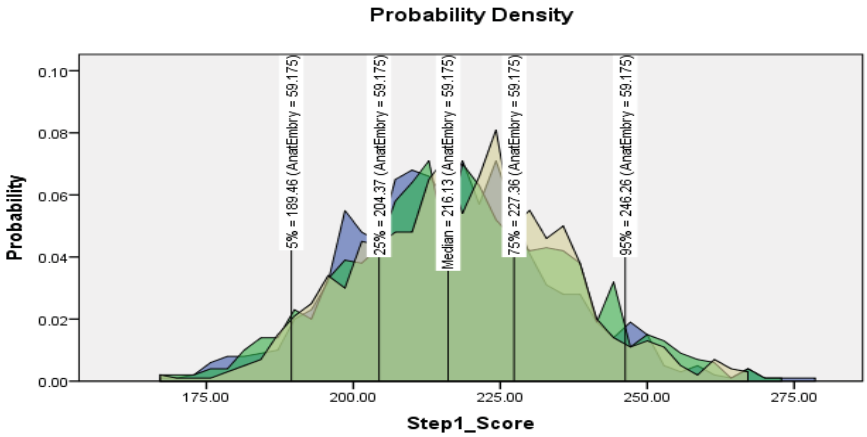


Fig. 2 Tornado Chart for Correlations with USMLE Step 1



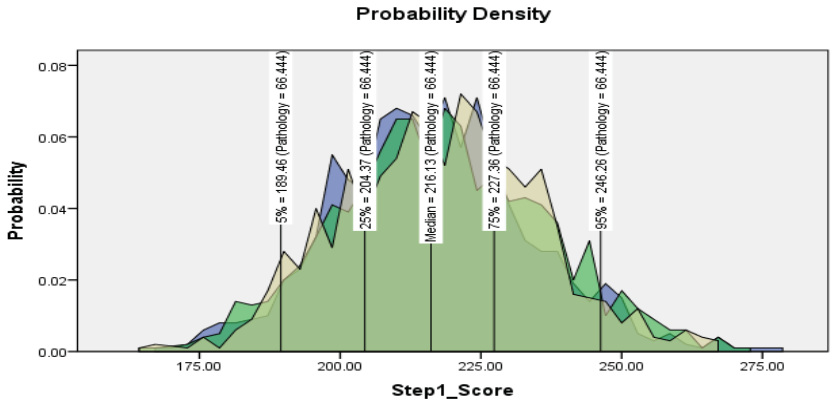
AnatEmbry: mean*	< 189.46	189.46 - 246.26	> 246.26
59.175	5%	90%	5%
64.175	6%	88%	6%
69.175	4%	91%	5%

*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 Embryology 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 the percentage of the USMLE Step 1 score in the intervals less than 189.46 and greater than 246.26 remained at 5% and the percentage of the USMLE Step 1 score in the interval of 189.46 - 246.26 remained at 90% if the NBME Pathology score increased by 10 points (from 66.444 to 76.444). Therefore, the NBME Pathology score had almost no effect on the USMLE Step 1 performance. Also, if the NBME Pathology score increased by five points (from 66.444 to 71.444), the USMLE Step 1 score 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 of one point (from 217.863 to 217.943).

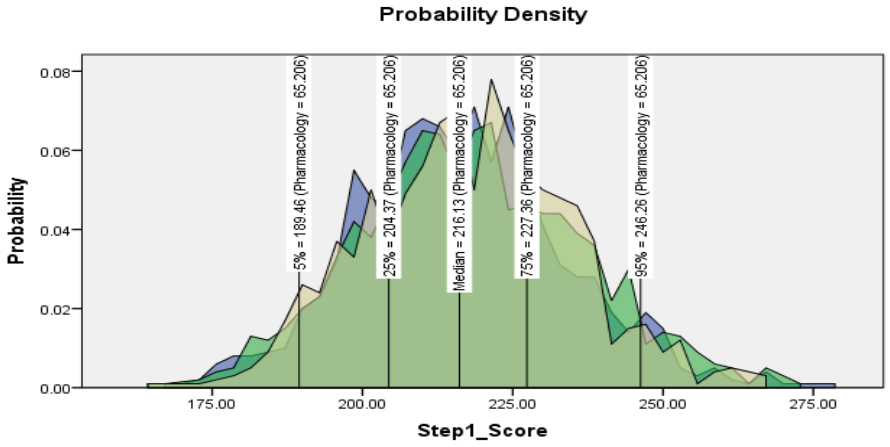


Pathology: a*	< 189.46	189.46 - 246.26	> 246.26
66.444	5%	90%	5%
71.444	6%	88%	6%
76.444	5%	90%	5%

*Sensitivity analysis based on iterations of input field: Pathology. Fixed distribution parameters: b=4.775 c=.000

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



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%

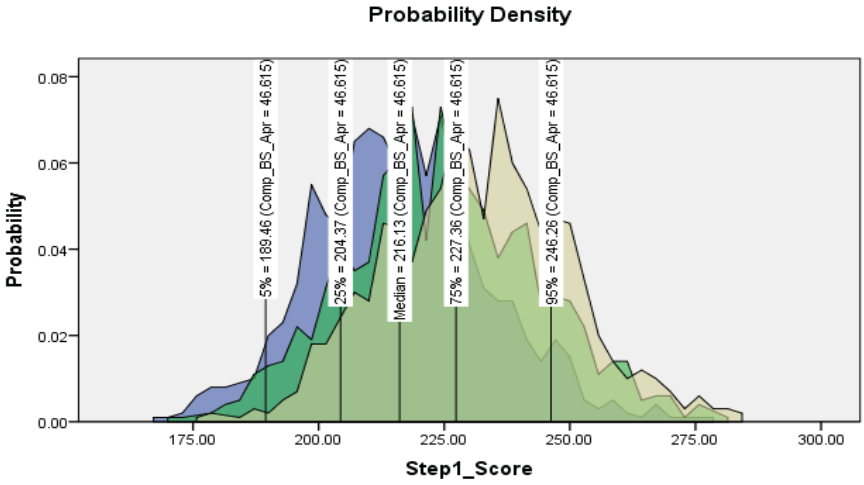
*Sensitivity analysis based on iterations of input field: Pharmacology. Fixed distribution parameters: stddev=12.219

Input Variable	Input Variable Changes	Outcome Changes (USMLE Step 1 Score)	95% Confidence Interval for USMLE Step 1 Mean Score	
			Lower	Upper
NBME Pharmacology 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 results showed the percentage of the USMLE Step 1 score in the intervals less than 189.46 and greater than 246.26 remained at 5% and the percentage of the USMLE Step 1 score in the interval of 189.46 - 246.26 remained at 90% if the NBME Pharmacology score increased by 10 points (from 65.208 to 75.208). Therefore, the NBME Pharmacology score had almost no effect on the USMLE Step 1 performance. Also, 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).

The USMLE Step 1 score distribution in the interval being less than 189.46 decreased from 5% to 1% and the percentage of the USMLE Step 1 score in the interval of 189.46-246.26 decreased from 90% to 78% if the NBME Comprehensive Basic Science score from April administration increased by 10 points (from 46.615 to 56.615). Therefore, the NBME Comprehensive Basic Science score from April administration had a great effect on the USMLE Step 1 performance. Also, a huge increase from 5% to 21% was present in the upper tail (with the score 246.26 as the cutoff point), indicating that sixteen percent of the students were more likely to achieve the highest score. In addition, the study found that if the NBME Comprehensive Basic Science score from April administration 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 administration 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

E. USMLE Step 2 Prediction Results

Linear regression model yielded the R squared value of 0.53, indicating that sixteen explanatory variables combined (See Table III) account for 53% of the variance in the USMLE Step 2 score. Also, 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.

Of the sixteen predictors used 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 eight points less than female students. MCAT Verbal Reasoning score positively and significantly contributed to the

USMLE Step 2 performances with p less than the .05 significance level, showing that a two-point increment of MCAT Verbal Reasoning score led to an increase of the USMLE Step 1 score 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 performance. 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 first attempt performance: 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 the NBME Comprehensive Basic Science Subject Board scores from the April examination.

F. Range Estimations of the USMLE Step 2 Score

The simulation model via linear regression showed that the explanatory variables contributed to the USMLE Step 2 score. Fig. 7 displayed the probability density function (PDF) of the USMLE Step 2 score 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. Also, 25% of all medical students had the USMLE Step 2 score over 234.12, and only 5% of all medical students had a USMLE Step 2 score greater than 245.57.

TABLE III
LINEAR REGRESSION FOR USMLE STEP 2

Variables in Equation	Unstandardized Coefficients (β or Slope)	Standardized Coefficients (Beta)	P Value
(Constant)	85.527		.000
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
VR	1.246	.115	.037*
PS	.923	-.084	.211
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

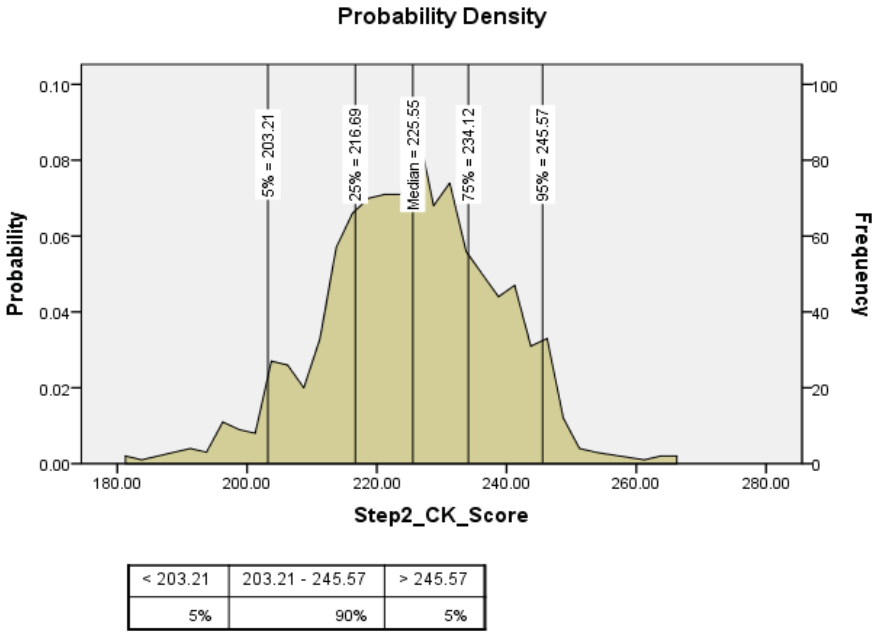


Fig. 7 Probability Density Function for USMLE Step 2

G. Variables Importance for USMLE Step 2

As shown in Fig. 8, the three highest explanatory variables correlated with the USMLE Step 2 scores were the Comprehensive NBME Basic Science Subject Board Score from April administration (r=0.89), the USMLE Step 1 Score (r=0.88), and the Comprehensive NBME Basic Science Subject Board Score from January administration (r=0.77).

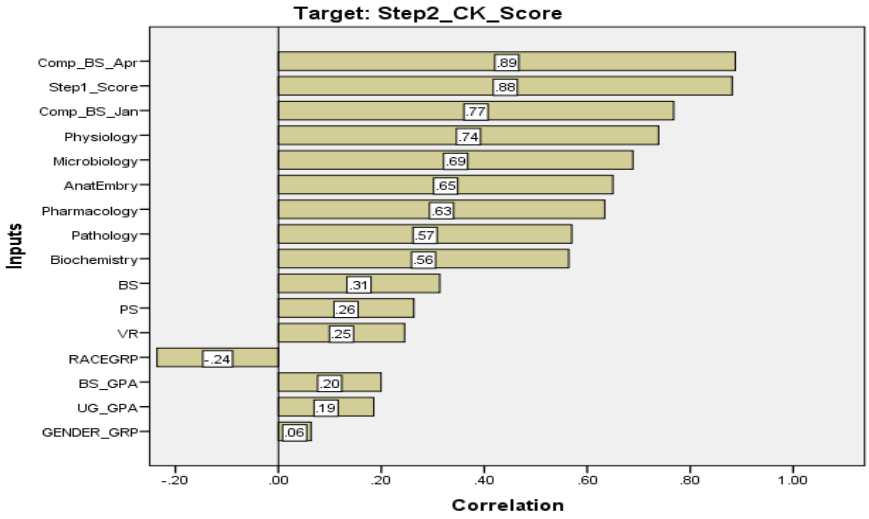
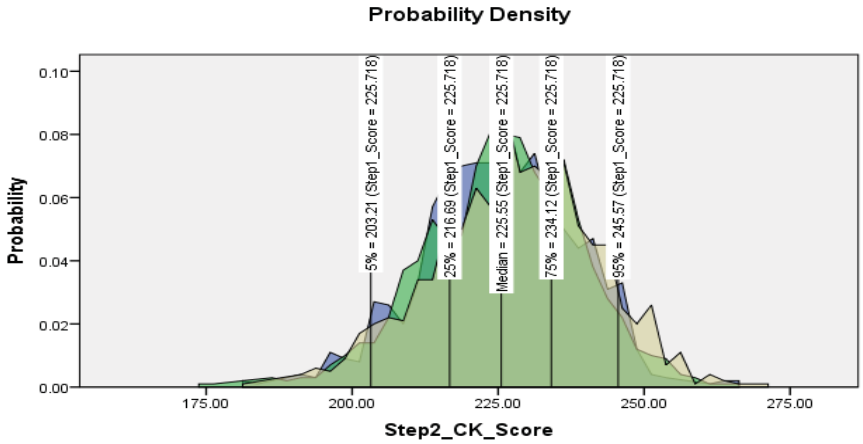


Fig. 8 Tornado Chart for Correlations with USMLE Step 2

H. Sensitivity Analysis for USMLE Step 2 Score

The study results showed that the upper tail (with the score 245.57 as a cutoff point) of the USMLE Step 2 score distribution (see Fig. 9) would increase from 5% to 9%, indicating that 4% of students were likely to achieve the highest score if the USMLE Step 1 score increased by 10 points from 225.718 to 235.718. Therefore, the USMLE Step 1 score had an effect on the USMLE Step 2 performance. Also, if the USMLE Step 1 score increased by five points (from 225.718 to 230.718), the USMLE Step 2 score in sensitivity analysis would increase by 0.610 points (from 225.026 to 225.636). However, if the USMLE Step 1 score increased an additional five points (from 230.718 to 235.718), the USMLE Step 2 score would rise by two points (from 225.636 to 227.701).



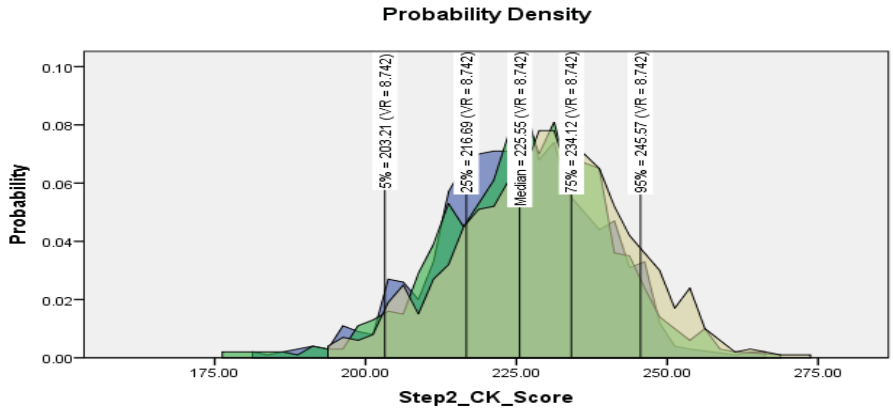
Step1_Score: a*	< 203.21	203.21 - 245.57	> 245.57
225.718	5%	90%	5%
230.718	5%	89%	5%
235.718	5%	86%	9%

*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 upper tail (with the score 245.57 as a cutoff point) of the USMLE Step 2 score distribution (see Fig. 10) would surge from 5% to 12% of the examination takers if the MCAT verbal Reasoning score increased by four points from 8.742 to 12.742, signifying that 7% of the total students were likely to achieve the highest score. Therefore, the MCAT Verbal Reasoning score had an effect on the USMLE Step 2 performance. 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

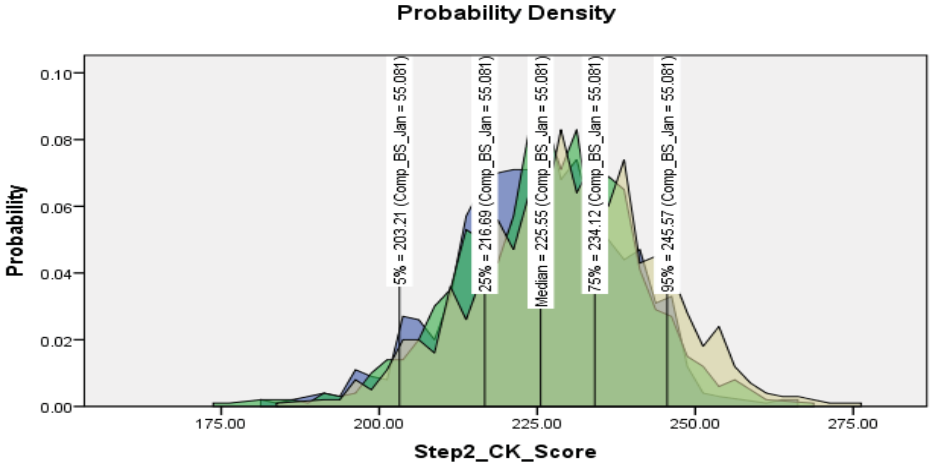
As shown in Fig. 11, a 10-point increment from 55.081 to 65.081 in the NBME Comprehensive Subject Board score from the January examination offered its contribution to the rise of the upper tail found in the USMLE Step 2 score distribution by 5% (from 8% to 13%), indicating that 5% of students were likely to achieve the highest 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 the 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, 8% of total students were more likely to achieve the highest score.

I. Summaries of Sensitivity Analysis for USMLE Steps 1 and 2

Sensitivity analysis results showed the magnitude of the effect of the NBME Subject Board scores on 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).



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

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 Regression Model (Per Unit Change in Input) from Table II
NBME Anatomy and Embryology Score	59.175	216.364	0.229	0.240
	69.175	218.654		
NBME Pathology Score	66.444	216.364	0.158	0.184
	76.444	217.943		
NBME Pharmacology 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		

Sensitivity analysis results showed the magnitude of the effect of the USMLE Step 1 score on 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 0.472 point as a result of the one-point increment in the NBME Comprehensive Basic Science Subject Board Score from the 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 the simulation model, were close to each other. The slope (0.473) of the NBME Comprehensive Subject Board score in January examination linear regression compared to a sensitivity ratio (0.472) of the same discipline in the simulation model were similar. Likewise, the slope (0.286) of the USMLE Step 1 score in liner regression showed 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 Regression 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		

VI. CONCLUSION

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 performance on licensure examination. 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 performance. In addition, the prediction model could help institutions document the effectiveness of basic science education programs because the USMLE Step 2 student 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 scores 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 score 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 performance. The HSRT is created specifically to measure critical thinking of health science trainees and professionals as well as predict licensure and clinical performance ratings. This test is used by educational researchers and employers in various health science settings due to its capability to provide data for learning outcome assessments [20]. Also, this study should examine the relationship between Objective Structured Clinical Examinations (OSCE) and USMLE Step 2, taking into account their correlation with the other predictors. The total OSCE score was significantly associated with USMLE Step 2 performance [21].

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