Medical Student Education

Medical School Curricula: Do Curricular Approaches Affect Competence in Medicine?

Kent Hecker, PhD; Claudio Violato, PhD

Background and Objectives: US medical school curricula continually undergo reform. The effect of formal curricular approaches (course organization and pedagogical techniques) on competence in medicine as measured by the United States Medical Licensing Examinations (USMLE) Step 1, 2, and 3 is not fully understood. The purpose of this study was to investigate the effects of formal curricular approaches in a latent variable path analysis model of achievement-aptitude-competence in medicine.

Methods: Using Association of American Medical Colleges (AAMC) and USMLE longitudinal data (1994–2004) for 116 medical schools, structural equation modeling was used to study latent variable path models assessing the impact of curriculum on competence in medicine (n=9,332). Results: A latent variable path model consisting of three latent variables measured by undergraduate grade point average (general achievement), Medical College Admission Test subscores (aptitude for medicine), and USMLE Step 1–3 (competence in medicine) was used to assess the impact of curriculum on competence in medicine. Two models were tested; one resulted in a Comparative Fit Index=.931 with a path coefficient of 0.04 from curriculum to competence in medicine. While there was a good fit of the data to the final model, the type of school curriculum did not significantly influence competence in medicine since it accounted for less than 1% of the variation in student performance on the USMLE.

Conclusions: Various formal curricular approaches have little differential effect on students’ performance on the USMLE.

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Medical school curricula reflect how schools conceptualize the relationship between basic and clinical sciences, with courses and learning experiences meant to advance students through the clinical reasoning process from novice to expert. The organization of basic science, clinical material, and learning experiences, therefore, should influence a student’s performance on outcome measures. To test this proposition, theoretical models to measure the effect of different curricula on student outcomes can be modeled and tested. To date, however, school-to-school studies are few, and only recently has there been a conceptual model of “general achievement-aptitude for medicine-competence in medicine” by which we can test the influence of curricula on competence in medicine as measured by licensure exams, such as the United States Medical Licensing Examinations (USMLE).

The most susceptible component to reform in the educational process is the curriculum (other elements include teachers, students, and infrastructure). Arguably, curricula are the most often changed aspects of medical education because they are the most recognized and easily modified. For the present study, curriculum is defined as “all the learning which is planned and guided by the school, whether it is carried on in groups or individually, inside or outside the school.” This definition of curriculum was chosen since it refers specifically to the formal curriculum, and hidden and informal curriculum were not assessed in our study.

Formal medical curricular approaches in the United States and Canada can be categorized into five major categories. They include the apprenticeship model (1765 to present), the discipline-based model (1871 to present), the organ-system-based model (1951 to present), the problem-based learning (PBL) model (1971 to present), and the clinical presentation (CP)-based model (1991 to present). Papa and Harasym’ and Hecker and

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Violato3 provide detailed descriptions of each curricular model. Pedagogical methods are subsumed within the various curricular structures, and it has been argued that medical teaching methods have been heavily influenced by the constructivist, student-centered educational theories of John Dewey.8,9 The application to classroom settings is still uncertain, however.10,11

Regardless of curricular approach, medical curriculum renewal (course reorganization and pedagogical techniques) is a continuous process. But, there is rarely a systematic and evidence-based approach to the identification, implementation, and evaluation of curricular changes. The question “Does school-level curriculum renewal, reflected by changes to formal curricular structures and supporting pedagogical techniques, significantly influence student learning outcomes?” has not been addressed systematically in medical education research.

Structural Equation Modeling (SEM), specifically latent variable path analysis, provides a mechanism to model hypothesized relationships between latent factors. SEM has had limited use in medical education research, but it can provide a mechanism to test integrated theoretical models in medical education.12 In two recent reports, Donnon and Violato3 and Collin et al13 tested hypothesized latent variable models to explain the relationship between the latent variables aptitude for medicine as measured by the Medical College Admissions Test (MCAT), general achievement as measured by premedical undergraduate grade point average (GPA), and competence in medicine, as measured by scores on licensure exams such as the USMLE Step 1–3 and Medical Council of Canada Part I. The models account for variability in indicators of success (eg, academic performance, performance on licensure exams) in medical school and beyond. This type of model can be used as a framework by which to assess the effect of medical school curricula on competence in medicine.

The primary research question for the present study was “Can we identify and model factors responsible for successful student performance in medical school and beyond, combining the influence of medical school curriculum, prior achievement (ie, premedical school grade average), and entry level status (ie, MCAT scores)?”

Methods

Data Source

This study received ethical approval from the Conjoint Health Research Ethics Board of the University of Calgary. Anonymous data from students who had applied for medical school from 1991 to 2001 (n=859,710) were obtained from the Association of American Medical Colleges (AAMC) and the National Board of Medical Examiners (NBME). These data included (1) premedical GPA, (2) MCAT subtests including biological sciences (BS), physical sciences (PS), writing sample (WS), and verbal reasoning (VR), (3) USMLE Step 1, 2, and 3 scores, and (4) age at start of medical school and school attended, for all accredited medical schools registered with AAMC. For those students accepted to medical school, data were included if there were recorded scores for the MCAT subtests, GPA, and recorded first-time scores for at least USMLE Step 1, as well as Step 2, and Step 3 (n=104,983). The data were organized by year of entry into medical school. The final data set contained longitudinal data for 8 years (1992–1999) for Step 1 and 2 and 7 years (1992–1998) for Step 3. This corresponded to the first cohort (1992) taking Step 1 in 1994 and the final cohort (1998) taking Step 3 in 2004.

Medical school curricular approaches from 116 schools were coded from the AAMC Curriculum Directories (1993–2000) according to the approach used by Hecker and Violato3 and were included in the final data set noted above. The curricular approaches are shown in Table 1.

Sampling

A random sample of 20% was selected without replacement from the combined NBME/AAMC data set. SEM requires large sample sizes. For SEM a small sample size is considered less than 100, medium sample size ranges between 100–200, and large sample sizes are over 200.13 All variables (GPA, MCAT, and USMLE scores) must be present to be included in the final model. Given the longitudinal nature of the data, some data points would not include GPAs from year

<p>| Table 1 |</p>
<table>
<thead>
<tr>
<th>Curricular Approaches Coded From the AAMC Curriculum Directories</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Disciplines based</strong>—courses such as anatomy, physiology, biochemistry, and genetics are taught in the first year, and pathology, neurosciences and pharmacology are present in the second year.</td>
</tr>
<tr>
<td>2. <strong>Organ-system based</strong>—where the disciplines are taught in the respective organ system, and courses such as renal, digestive, and endocrine are evident in the first 2 years.</td>
</tr>
<tr>
<td>3. <strong>Discipline based first year and organ system based second year</strong>—first-year courses typically consist of biochemistry, anatomy, physiology, and genetics, and second-year courses consist of endocrine, renal, digestive, etc.</td>
</tr>
<tr>
<td>4. <strong>Other/multi-track</strong>—universities offering multi-track programs, listing courses such as Doctoring I and II without a definition of the content, etc.</td>
</tr>
<tr>
<td>5. <strong>Problem-based learning (PBL)</strong>—programs that have an identified PBL component that has been made explicit in the curriculum directory. This might include courses such as “Problem-based Learning” or stated problem-based components in all the courses presented in the curriculum. For verification, the numbers of hours in tutorials or cases were referred to for clarification since PBL is primarily disseminated through the use of tutorials.</td>
</tr>
</tbody>
</table>

AAMC—Association of American Medical Colleges
there were 5,009 that attended discipline-based towns, 24.8 (SD=3.7; 57% male, 43% female). Of the 9,332 stu-
for our analysis. The mean age at matriculation was the variables (as a result of list-wise deletions) necessary and competence in medicine. tested assessing the relationship between curriculum to competence in medicine. Two models were initial framework to explore the relationships of cur-
value less than 0.1 indicates acceptable model fit. differences between actual and modeled correlations. For the model. SRMR may be viewed as a standardized dif-
variables. It is an index of congruence between the model and the data ranging from 0 to 1, with 0 denot-
ing a model where all variables are uncorrelated, while 1 indicates a situation where the covariance structure has reasonably good fit with the theoretical model. A commonly used criterion is CFI<0.9 denotes an unsatisfactory model; if the CFI is 0.90 then 90% of the variance and covariance in the data is accounted for in the model. SRMR may be viewed as a standardized difference between actual and modeled correlations. For perfect model fit, the differences should be 0 with values of SRMR<0.10 being considered acceptable. RMSEA is an overall model fit chi-squared statistic adjusted for sample size and model degrees of freedom, for which a value less than 0.1 indicates acceptable model fit.

Since the patterns and relationships were originally explored by Collin et al,4 their model was used as an initial framework to explore the relationships of curriculum to competence in medicine. Two models were tested assessing the relationship between curriculum and competence in medicine.

Data Analysis
A Pearson product-moment correlation matrix between GPA, MCAT subscores, age, USMLE Step scores, and curricular types was first analyzed and based on the results a latent variable path model was developed and tested using EQS 6.1.14 Using maximum likelihood (ML) estimation, the model was fit to a covariance matrix. The fit indices used were Bentler’s comparative fit index (CFI), standardized root mean squared residual (SRMR), and the root mean squared error of approximation (RMSEA).

These descriptive fit indices measure the extent to which a SEM corresponds to the empirical data. Typically, values of these measures range from zero (no fit) to one (perfect fit), while some provide a badness of fit with parameters of zero to one. CFI compares the fit of the proposed theoretical model to the fit of a baseline model with zero covariances between the observed variables. It is an index of congruence between the model and the data ranging from 0 to 1, with 0 denoting a model where all variables are uncorrelated, while 1 indicates a situation where the covariance structure does reasonably good fit with the theoretical model. A commonly used criterion is CFI<0.9 denotes an unsatisfactory model; if the CFI is 0.90 then 90% of the variance and covariance in the data is accounted for in the model. SRMR may be viewed as a standardized difference between actual and modeled correlations. For perfect model fit, the differences should be 0 with values of SRMR<0.10 being considered acceptable. RMSEA is an overall model fit chi-squared statistic adjusted for sample size and model degrees of freedom, for which a value less than 0.1 indicates acceptable model fit.

Results
From the random sample of 20%, 9,332 contained all the variables (as a result of list-wise deletions) necessary for our analysis. The mean age at matriculation was 24.8 (SD=3.7; 57% male, 43% female). Of the 9,332 students, there were 5,009 that attended discipline-based curricular-based schools, 556 systems based, 1,403 discipline first year and systems second year, 1,003 from a multi-track or other curricular structure, and 1,361 from a PBL-based curricular structure or component. Means, standard deviations, and intercorrelations of all the variables are presented in Table 2.

Correlations
As shown in Table 2, the Pearson correlation coefficients range from no relationship (r=0.00) between curriculum and verbal reasoning (VR) to strong relationships (r=.76, P<.01) between Step 1 and Step 2. The writing sample subtest was not included since it has been shown not to account for a large amount of variance in Step 1–3.15,16 Although most were significantly correlated, the correlations should be assessed cautiously due to the large sample size. Moderate to strong correlations were shown between similar measures, namely between the subscales of the MCAT, GPA, and scores on Step 1–3.

Latent Variable Path Analysis
Based on reported curricular effects and the results of the correlation analysis, 12 variables were included to test the hypotheses of the effect of curriculum on student learning outcomes. Figures 1 and 2 are hypothesized models regarding the influence of curricular structures on competence in medicine. Figure 1 includes curricular structure as an observed nominal variable that mediates the effect of general achievement and aptitude on competence in medicine. The values for the fit indices were CFI=0.861 and SRMR=0.163, which, for CFI, was less than the 0.90 cut-off and greater than 0.10 for SRMR, indicating that this model did not fit the data very well. Further, the path coefficients between aptitude for medicine (0.03) to curricular structure, from general achievement (0.05) to curricular structure, and from curricular structure to competence in medicine (0.07) were near zero—indicating that the observed construct for curricular structure does not introduce an effect on competence in medicine.

Figure 2 tests the proposition that curricular structure has an influence on competence in medicine as an exogenous moderator variable. The values for the fit indices were CFI=0.931, SRMR=0.038, and RMSEA= 0.084, indicating that this model did fit the data. As an example of how to read the model, the values with the straight arrows are path coefficients similar to multiple regression coefficients, and the value with the curved arrow is a correlation coefficient. For instance, General Achievement is identified by premedical GPA Year 1, GPA Year 2, GPA Year 3, and GPA Year 4 with path coefficients ranging from 0.69 to 0.82. Squaring the path coefficients provides an indication as to the amount of variance accounted for by that measured variable. For example, Year 1 GPA with a path coefficient of 0.69
accounts for 47.6% of the variance. More detail on how to read SEM models is available from other sources.12

The majority of the path coefficients showed the same pattern with Figure 1, in which the highest path coefficients were between the observed variable, Step 2 scores, and the latent construct competence in medicine. The path coefficient for the observed exogenous variable curricular structure was very small (0.04). The path accounts for less than 1% of the variance, indicating that curriculum is unrelated to competence in medicine. In other words, while the model demonstrated good fit to the data, the type of curricular structure did not affect competence in medicine.

**Discussion**

The findings of our study indicate that of the two models tested, only one, the model with curricular structures as an exogenous variable, had an acceptable fit (Figure 2). This exogenous variable did not have a significant influence on competence in medicine, however, as the path coefficient was close to zero (0.04). The findings from the SEM analyses suggest that formal curricular approaches do not significantly influence competence in medicine as measured by USMLE Step 1–3 scores.

Curriculum renewal appears to be a continuous process within medical schools.17,18 These changes, however, have been primarily at the preclinical basic science years, and little change has occurred to the clinical years of undergraduate programs.19 Assessment of the influence of various medical curricula on educational outcomes has been limited both within and between schools and has been performed primarily on the acquisition and application of knowledge in basic sciences and clinical performance. Results of previous studies of the effects of medical curriculum on student outcomes were mainly nonsignificant with small effects, suggesting that the changed curricula or educational approach has little effect on performance. The limitations of these studies have been that they have primarily compared student performance in various curricula within institution and rarely were between institution comparisons done over multiple years.

Unlike previous curriculum research, our study has school population-level data with standardized incoming and outgoing measures across multiple years during which curricular structures have changed. Using structural equation modeling it has been possible to assess the effects of curricula on competence in medicine as measured by USMLE Step 1–3, and the results suggest that the effect is small.

**Table 2**

Pearson Product Moment Correlation of Age, GPA, MCAT, USMLE (Step1–3), and Curricular Types (n=9,332)

<table>
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<th></th>
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<th>VR</th>
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<th>S2</th>
<th>S3</th>
<th>GPA y1</th>
<th>GPA y2</th>
<th>GPA y3</th>
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<td>9.49</td>
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<td>2.00</td>
<td>1.78</td>
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<td>0.40</td>
<td>0.39</td>
<td>1.58</td>
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</table>

* Correlation is significant at the 0.01 level (2-tailed).
† Correlation is significant at the 0.05 level (2-tailed).

MCAT—Medical College Admission Test, USMLE—US Medical Licensing Examinations, BS—biological sciences, PS—physical sciences, VR—verbal reasoning, S1—USMLE Step 1 exam, S2—USMLE Step 2 exam, S3—USMLE Step 3 exam, GPA—premedical undergraduate grade point average, y1—first year, y2—second year, y3—third year, y4—fourth year.
Limitations

There are limitations to our study, as many factors make assessment of the effectiveness of stated medical curricular approaches both within and between schools difficult. First, self-reported curricular approaches are not consistent among schools. While certain schools report that they have a PBL curriculum, others state that they have an organ system-based curriculum that is mainly taught through a PBL format. The curricular categories used in our study were based on reported curricular structures and had been used in a previous study with the addition of the PBL category.1

Second, there is a criterion-related problem with the use of licensure exams as the only educational outcome measure. These examinations measure declarative knowledge and some clinical reasoning skill, and some argue these exams do not assess important physician competencies such as problem solving, clinical reasoning, and empathy, which may be objectives of some medical schools. While this is a typical criticism, there are no other standardized educational outcomes used between medical schools, and candidates must pass at least USMLE Step 3 to practice medicine. Further, since the data set was collected, the format of the USMLE Step 2 exam has changed to assess clinical skills.

Third, there is homogeneity of the student population in this study. While medical schools have varying selection criteria, all medical students have excelled academically throughout their premedical schooling and, regardless of the type of medical curriculum, the expectation is that they will perform well enough on the USMLE to become practicing physicians.

Figure 1

Model of Competence in Medicine With Curricular Structure as a Mediator Variable

Latent variable path analysis of undergraduate premedical grade-point average (GPA), Medical College Admissions Test (MCAT) scores, United States Medical Licensing Exam (USMLE) Steps 1–3 scores, and Curricular Structure Using Maximum Likelihood (ML) Estimation (n=9,332), Fit Indices: $\chi^2 (49)=6511.35$, $P<.001$; Comparative Fit Index (CFI)=0.861; Root Mean Squared Error of Approximation (RMSEA)=0.119; Standardized Root Mean Squared Residual (SRMR)=0.163. Other abbreviations: $y_1$—first year, $y_2$—second year, $y_3$—third year, $y_4$—fourth year, BS—MCAT biological sciences score, PS—MCAT physical sciences score, VR—MCAT verbal reasoning score. See text for additional interpretation.
Fourth, we did not have standardized teacher-level data (eg, teacher effectiveness, formal education in teaching methods, contact hours, etc). Medical school-level studies rarely focus on the knowledge, skills, and attitudes of the teachers or the central dyad of the student-teacher interaction, even though studies have found that student learning is enhanced by the presence of an expert in an active learning environment and by instructors who have a working knowledge of teaching/learning methods and assessment techniques.20,21 The theoretical framework proposed by Collin et al4 provides a template to assess other school-level constructs and teacher-level variables that theoretically could moderate competence in medicine. Practically, this can be attempted within medical schools that have rich data on quality of instruction, which could include level of teacher training, student contact hours, and student feedback.

Conclusions

The main result of our study was that formal medical school curricula, which reflects how schools conceptualize the relationship between basic and clinical sciences, do not have much effect on USMLE performance. These findings and the results of Hecker and Violato3 demonstrate that the greatest variation in
performance is between students within schools, not between schools.

Thus, while a curriculum is important, the emphasis that so many medical schools place on curriculum renewal might be reconsidered. We reiterate the statement made by Ripkey that “Overall curricular approach may be less important than the quality of the curriculum implementation…” This suggests that in medical education reform there should be a shift from curriculum restructuring to conducting more meaningful research on areas such as student characteristics, quality of medical educators, and the proper use of learning theory, educational theory, assessment, and pedagogical techniques on the student-teacher relationship in the context of medical education.

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