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Factors Associated with Healthcare Students' Cognitive Levels Measured by the Classroom Test of Scientific Reasoning.

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Factors Associated with Healthcare Students' Cognitive Levels Measured by the Classroom Test of Scientific Reasoning.

Abstract

Introduction: Healthcare student acceptance into graduate and professional school is based on Grade Point Average (GPA), Graduate Record Examination (GRE) scores, interviews, and letters of recommendation, but not on cognition levels. However, educators need to understand students' cognitive levels to facilitate constructivist learning theory and inquiry-based learning. The aim of this study is to understand the influence of cognition in healthcare students through the administration of the Classroom Test of Scientific Reasoning (CTSR).

Methods: Medical and baccalaureate nursing students were enrolled to answer demographic questions and complete the CTSR. The CTSR rubric score were used to define four operational cognitive levels for potential association with covariates.

Results: Mean rubric CTSR scores were higher in medical than nursing students (ρ

Conclusions: As pedagogical studies are conducted, information on healthcare students' cognition is needed. Our study shows that CTSR rubric scores (cognition) were significantly associated with professional preference and age. We suggest future studies to evaluate the need for cognition evaluation at admission to help the students to choose a specialty that most appropriately matches their cognitive level.

Keywords

Classroom Test of Scientific Reasoning, Cognition levels, Medical students, Nursing students

Factors Associated With Healthcare Students' Cognitive Levels Measured by the Classroom Test of Scientific Reasoning

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Abstract

Introduction: Healthcare student acceptance into graduate and professional school is based on Grade Point Average (GPA), Graduate Record Examination (GRE) scores, interviews, and letters of recommendation, but not on cognition levels. However, educators need to understand students' cognitive levels to facilitate constructivist learning theory and inquiry-based learning. The aim of this study is to understand the influence of cognition in healthcare students through the administration of the Classroom Test of Scientific Reasoning (CTSR).

Methods: Medical and baccalaureate nursing students were enrolled to answer demographic questions and complete the CTSR. The CTSR rubric scores were used to define four operational cognitive levels for potential association with covariates.

Results: Mean rubric CTSR scores were higher in medical than nursing students (ρ<0.0001). Medical students (95.6%) demonstrated high transitional and formal operational cognitive levels. Nursing students (69.8%) were concrete operational and low transitional. Multiple regression analysis showed that profession (p<0.0001) and age (p<0.03) were independently associated with the CTSR mean rubric score. After adjustment for these variables, gender and years of schooling were unassociated with mean rubric scores. After adjusting for the profession, gender became borderline statistically significant (p=0.05).

Conclusion: As pedagogical studies are conducted, information on healthcare students' cognition is needed. Our study shows that CTSR rubric scores (cognition) were significantly associated with professional preference and age. We suggest future studies to evaluate the need for cognition evaluation at admission to help the students choose a specialty that most appropriately matches their cognitive level.

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Introduction

Advanced cognitive abilities play a vital role in guiding the decision-making process towards accurate conclusions.1 Nowhere is this more apparent than in the healthcare profession, where these abilities are critical in shaping outcomes that carry potentially life-and-death consequences.[1] One of the complex challenges encountered by professionals is accurate diagnoses and effective treatments. Unfortunately, current estimates indicate an alarmingly high rate of medical misdiagnosis, ranging from 10% to 20%.[2,3] According to Eddy et al., physicians disagree on a medical diagnosis in 10-50% of cases when evaluating the same patient.[4] Remarkably, 80% of these errors arise from a cascade of cognitive traps resulting from ineffective communication and inadequate training or supervision.[2,5]

Healthcare workers, including physicians, seldom make errors due to a deficiency in clinical knowledge. Instead, instances of misdiagnosis often stem from unwittingly falling into various cognitive traps.[6] Cognitive traps act as a barrier for healthcare professionals to explore alternate solutions beyond the familiar strategies that they normally apply.[7] These cognitive traps include, but are not limited to, focusing on conflicting hypotheses (including rare diagnoses), formulating diagnoses based on incomplete information, perception or confirmation bias by past experience or personal investments, anchoring on the obvious while failing to consider alternative diagnoses and stereotyping hypotheses. Additionally, they include hypothesizing in one's favorite discipline with favorable outcomes while ignoring rational supportive or contradictory evidence, recalling only the beginning and end of the patient interview, blaming patients for their illnesses instead of seeking alternative diagnoses, and concluding an interview prematurely.[8,9] Furthermore, certain healthcare professionals' preferred cognitive reasoning strategies may predispose them to fall into these traps.[6,10]

Despite its significance in the healthcare profession, little to no attention is placed on cognition during the admission process to medical or nursing schools, nor is cognitive development regarded as a critical component of student advancement.[11] Consequently, students are baffled by the challenges they encounter and struggle to apply their knowledge in diverse medical scenarios. It is imperative for educators to foster the intellectual growth of healthcare students by using cognitive acceleration study materials as a tool to support and apply constructivist learning theory and inquiry-based teaching methods.[12,13] There's a general consensus that students acquire new material either through repetition or by connecting new information with their existing knowledge.[14] In the latter technique, students learn by encountering puzzling observations and attempting to explain them through if/then/therefore cycles of hypothetico-deductive reasoning.[14] New ideas stimulate neural activity, creating new neural connections and associating them with prior ideas. Students who excel at hypothetico-deductive reasoning are more adept at learning and constructing new knowledge.[15] Therefore, the primary aim for instructors is to cultivate meaningful and lasting learning. This requires the medical and nursing students to engage in the generation of new information and evaluation of their self-generated ideas. This implies that laboratory and field-based activities may be the most effective instructional vehicles for this population of students.[4]

The Lawson Classroom Test of Scientific Reasoning (CTSR) evolved from the Test of Scientific Reasoning (TOSR).[16] The CTSR was developed by Anton Lawson to measure habitual or preferred reasoning strategies. Although originally developed in 1978 and later revised in 2000,[17] the CTSR is still widely used to measure various aspects of scientific reasoning and can readily be administered and scored in the classroom setting. It involves physical concepts requiring minimal to little preparation and includes a variety of question types that assure reliability.[7] The CTSR measures concrete, transitional and formal operational reasoning levels. The CTSR stimulates participants to demonstrate the use of these operations during the isolation and control of variables, the combinatorial analysis of possible causal factors (combinatorial reasoning), the weighing of confirming and disconfirming cases (correlational reasoning), the recognition of the probabilistic nature of phenomena (probabilistic reasoning), and the eventual establishment of functional relationships among variables (proportional reasoning).[18]

There is published evidence that students start to develop basic reasoning abilities around their college years.[19] However, Vierula et al. demonstrated that undergraduate nursing applicants' reasoning skills vary during the selection process.[20] Even though students can enter into a program with different reasoning skills, educational strategies aimed at developing reasoning skills can promote their development.[21] In order to gain a better understanding of clinicians' cognitive abilities and the factors influencing their development, we investigated the cognition and reasoning strategies of medical and nursing students using the CTSR assessment. We compared nursing and medical students to investigate if the two groups differ in their cognitive abilities and if the decision to choose a certain profession is associated with a certain domain of reasoning skills.

Methods

After obtaining the Institutional Review Board (IRB # 3211) approval, medical and baccalaureate nursing students were invited to participate in the study. Baccalaureate nursing students in their first semesters of nursing school were approached by their instructor and recruited at a one-time presentation. Medical students were recruited by fellow students through announcements during lectures, meetings, and e-mails. Medical students were also recruited by faculty at various times: 7% at a one-time presentation for first year medical students, 8% at a one-time presentation for second year medical students, and 35% of third and fourth year medical students during their biweekly anesthesia clinical rotation. The recruitment period was three months, and the study cohort closed in five months.

After obtaining informed signed consent, students were asked to complete a questionnaire gathering information on demographics, education, and past work experiences before proceeding to take the CTSR test. The CTSR test was scored to assign each participant a score of 0-24 out of a maximum of 24 possible single correct answers. Most CTSR items ask the participant to identify the correct answer to a question, and then to identify the correct reasoning for choosing that answer. To get credit for the questions, the participant must choose both the correct answer as well as the correct reasoning for arriving at that answer. If one or both responses to the first 10 paired questions are incorrect, no point is awarded for that question. The last two paired hypothetico-deductive reasoning questions offer independent credit, one point each, for the correct answer and the correct reasoning. Therefore, the maximum CTSR rubric point score for these 24 original questions (12 pairs) is a final score of 0-14 points [10 points for the first 20 combined items (ten pairs), and four points for the last four questions or two pairs]. The four operational cognitive levels of the participants are based on the CTSR rubric score: 0-4 correct answers = concrete operational thinking; 5-7 correct answers = low transitional thinking; 8-10 = high transitional thinking; 11-14 correct answers = formal thinking.[12,18]

Data were analyzed using SAS software version 9.3 (SAS Institute, Inc., Cary, NC). The mean CTSR rubric scores were compared using t-tests between medical and nursing students, and among male and female students within each group. A two-factor analysis of variance examined the joint effects of professional program and gender on mean CTSR rubric scores. Chi-square tests were used to assess associations between the students' cognitive level and their professional program and gender. Linear regression was used to examine the association of mean CTSR rubric scores and age, and the association between the mean CTSR rubric scores and years of schooling. Multiple regression analysis was performed for any association between the CTSR rubric scores and years of schooling while adjusting for the effect of age. Multiple regression analysis was also used to find any association between CTSR rubric scores and gender, educational program (medical versus nursing), years of schooling, and age. Demographic data (gender, years of schooling, and age) were compared between students in the medical and nursing programs.

Results

A total of 57 female and 30 male students ($n = 87$), ages 20 to 39 years (mean = 24.5 years; SD = 4.4) were enrolled in the study. **Table 1** shows the composition of the study participants. The number of years of schooling ranged from 14 to 26 years (mean = 17.1 years; SD = 2.3). Overall, 50.6% of students were medical students and 49.4% were baccalaureate nursing students.

Medical students' mean rubric CTSR scores were higher than those of baccalaureate nursing students ($p < 0.0001$) (**Table 2**) and the distribution of cognitive levels was associated with the type of student ($p < 0.0001$). Mean rubric scores did not differ between males and females among medical students ($p = 0.15$) or among baccalaureate nursing students ($p = 0.26$). After adjusting for educational program in a main effect analysis of variance model, mean CTSR rubric scores did not differ between males and females ($p = 0.21$). Fifty percent of the medical students were formal operational thinkers, followed by 45.6% high transitional and 4.5% low transitional. Seven percent of the baccalaureate nursing students were formal operational thinkers, followed by 23.2% high transitional, 44.2% low transitional and 25.6% concrete operational (**Table 3**).

Most females were in the low transitional operational thinker group (33.3%), with 17.5% concrete operational, 31.6% high transitional and 17.5% formal operational thinkers. Fifty percent of males were formal operational thinkers, with the remainder, 6.7% low transitional and 40% high transitional thinkers (Table 3).

Simple linear regression analyses showed a statistically significant association between mean rubric CTSR score and years of schooling ($p < 0.0003$) but no association with age ($p = 0.80$). After stratifying the linear regression analysis by the professional education program, the mean rubric CTSR score was not associated with age among medical ($p = 0.57$) as well as nursing students ($p = 0.08$). Similarly, there was no association between rubric CTSR score and years of schooling among medical ($p = 0.67$) and nursing students ($p = 0.71$). A multiple regression model including gender, years of schooling, profession, and age showed a statistically significant association between rubric CTSR score and profession ($p < 0.0001$) and age ($p = 0.03$) and a borderline association with gender ($p = 0.05$). This model showed no association between rubric CTSR and years of schooling ($p = 0.85$) (**Table 4**). Finally, the increase in age did not correlate with the increase in the number of years of schooling as the student developed from concrete operational to formal operational.

Table 1: Participants' Demographics.

	Professional Preference		
	Medical Students	Nursing Students	Totals
Total (%)	44 (50.6%)	43 (49.4%)	87 (100%)
Total Females (%)	19 (43.2%)	38 (88.4%)	57 (65.5%)
Total Males (%)	25 (56.8%)	5 (11.6%)	30 (34.5%)
Avg. Age (SD, Median, Range)	25.8 (3.2; 25; 22-37)	23.1 (5.1; 21; 20-39)	24.5 (4.4; 24; 20-39)
Avg. School Yrs. (SD, Median, Range)	18.5 (1.6; 18.5; 15-22)	15.7 (2.1; 15; 14-26)	17.1 (2.3; 17; 14-26)

Table 2. Comparison of CTSR Raw and Rubric Scores With Professional Preference and Sex.

	Number	Ave. CTSR Raw Score* (SD, 95% CL Mean)	Ave. CTSR Rubric Score (SD, 95% CL Mean)
Medical Students	44	20.2 (2.6; 19.4-20.9)	10.2 (2.0; 9.6-10.8)
Nursing Students	43	13.8 (4.3; 12.4-15.1)	6.2 (2.8; 5.3-7.0)
p-value		<0.0001	<0.0001
Males	30	20.2 (2.2; 19.4-21.0)	10.2 (2.0; 9.4-10.9)
Females	57	15.6 (4.9; 14.3-16.9)	7.4 (4.2; 6.5-8.2)
p-value		<0.0001	<0.0001

Table 3. Cognitive Classification by Sex and Professional Preference.

	Cognitive Classification			
	Concrete Operational	Low Transitional	High Transitional	Formal Operational
Total (%)	11 (12.6%)	21 (24.1%)	30 (34.5%)	25 (28.7%)
Total Females (%)	10 (17.5%)	19 (33.3%)	18 (31.6%)	10 (17.5%)
Total Males (%)	1 (3.3%)	2 (6.7%)	12 (40.0%)	15 (50.0%)
Nursing Students (%)	11 (25.6%)	19 (44.2%)	10 (23.2%)	3 (7.0%)
Medical Students (%)	0 (0%)	2 (4.5%)	20 (45.6%)	22 (50.0%)

Table 4. Multivariable Regression Model Between CSTR Rubric Scores and Covariates.

Covariates	DF	Type III SS	Mean Square	F-Value	Pr > F
Students	1	152.37199	152.3719856	27.89	< 0.001
Sex	1	21.285767	21.2857672	3.9	0.05
Age	1	27.252266	27.2522662	4.99	0.03
Years of Schooling	1	0.1826059	0.1826059	0.03	0.85
Source	**DF**	**SS**	**Mean Square**	**F-value**	**Pr > F**
Model	4	372.27798	93.0694947	17.03	<.0001
Error	80	437.13379	5.4641723		
Corrected Total	80	809.41176			

DF= Degree of Freedom; SS = Sum of Square

Discussion

While the CTSR has been extensively validated and utilized with Pre-K-12 students to evaluate cognitive developmental strategies, research at the college and post-graduate levels is scarce.[22-24] Bhaw et al. recently published results confirming the validity of the CTSR among engineering faculty students. They evaluated various dimensions and components of the CTSR and found statistically significant coherence among all CTSR dimensions.[25] Even though healthcare professionals are expected to utilize evidence-based, knowledge-driven problem-solving approaches for medical decisions,[1,26] their cognitive capacity to do so is seldom discussed. Perhaps, it is assumed that once the students enter college, they are "mature" in their problem-solving abilities, and only formal thinkers enter professional programs. Students in the medical field are expected to learn from lectures, through observation, during Grand Rounds, by rounding on patients, and experiential learning (learning by 'doing' at the bedside). Baccalaureate nursing students have similar learning experiences but with an increased emphasis on learning by "doing" clinical and simulation experiences throughout their education.

Concrete operational students demonstrate proficiency in logic but may struggle with abstract concepts and hypothetical scenarios. In contrast, formal operational students think abstractly, reason logically, and arrive at conclusions based on their knowledge. Transitional students occupy an intermediate position, showing some capability with hypothetical tasks.[24] Pedagogical studies on critical thinking are presently being used to design and implement newer teaching modules for healthcare education.[26,27] However, before embarking on these studies, it is imperative to assess healthcare students' current cognitive levels. This will allow tailoring strategies to advance each student's cognitive development. Our current study is such an effort to address the question of whether all healthcare students have comparable cognitive abilities when it comes to considering and rationalizing similar scenarios or if there are differences in their capacities to do so, and if so, what those differences might be.

The results show that rubric CTSR scores and the cognitive levels derived from these scores differed significantly between medical students and baccalaureate nursing students. The majority of medical students (95.6%) fall into the "high transitional" and "formal operational" categories, while approximately 70% of baccalaureate nursing students were "concrete operational" and "low transitional" thinkers. The mean rubric CTSR score was not associated with the years of schooling. On average, there was a difference of 2.1 years of schooling between concrete operational versus formal operational students. However, neither of the two factors was associated with the rubric CTSR score when medical and nursing students were analyzed separately. The data show that years of schooling do not play any significant role in the development of students' cognitive levels. Could the differences in the rubric CTSR scores and cognitive levels between medical and nursing students be due to the differences in content/material taught in medical versus baccalaureate nursing school? Or that the baccalaureate nursing students had limited nursing and upper-level undergraduate content to date? Perhaps the combination of differences in the age and teaching material between medical and baccalaureate nursing students accounts for the difference in cognitive abilities, considering age is significantly different among the two professional groups (p = 0.005). If we were not to account for this age difference, we would incorrectly compare second year college students (mostly nursing students) to first to fourth-year post-graduate students (mostly medical students) and attribute the statistical significance of the difference to their choice of profession (medical vs. nursing).

At the time of CTSR administration, baccalaureate nursing students completed approximately 3.3 fewer years of schooling education than medical students. Baccalaureate nursing school students are usually in the process of obtaining their first degree, while medical students are in post-graduate studies, typically having already earned a prior college or university degree. Since the number of schooling years was not associated with cognitive abilities in the multivariable model, it suggests that medical students' exposure to college-level material may shape their cognitive profile. Age, as identified in the final model, may be the key factor with a profound effect on the reasoning abilities of the students. Once baccalaureate nursing students reach a more advanced age comparable to that of medical students, their cognitive levels are equivalent to that of their medical student counterparts. One can always argue that the cognitive level of students led to professional preference, since some cognitive abilities are already developed at the time of entering the college/university,[14] or that being in one of the two professions shapes the reasoning abilities of the students. If the cognitive levels of the students determine professional preference, then the significant association between age and rubric becomes meaningless, and the cognitive levels of students are already developed long before they enter college. The final statistical model involving all the variables shows that both profession and age are the only factors significantly associated with cognitive levels. Whether or not age affects reasoning abilities in students, knowing the cognitive profile will help pre-college/university students to choose a field of study already aligned with their cognitive abilities.

In general, admission to medical and nursing schools is based on the Grade Point Average (GPA), standardized testing such as the Medical College Admission Test (MCAT) score, interview, and letters of recommendation. Only the MCAT exams measure cognitive skills related to the physical and biological sciences,[27] but are seldom considered stand-alone admission criteria.[28] Several studies have investigated the effectiveness of medical school admission criteria in predicting performance with varying results.[29-32] GPA is the grade-point-average (typically 0-4) based on a university/college accepted system. However, GPA does not reflect the class makeup, competition, level of the courses (advanced graduate courses), and course demand (same course with higher expectations from university A versus university B). According to Lynch et al., GPA and MCAT scores should be used cautiously as admission criteria for minority students.[33] Lastly, the interview and letters of recommendation reflect how well a student presents himself/herself and how others view him/her, with low predictive value for later performance in medical school.[33] None of the above four criteria for healthcare professionals used in the admission process address the cognitive capabilities of the students.

Studies have investigated gender-related differences in cognitive levels with varying results.[34-36] At first glance, this study shows a statistically significant difference in CTSR scores and cognition levels between males and females. Ninety percent of males were at the high transitional and formal operational levels, while approximately 65% of the females were at the low and high transitional operational levels. We noted that approximately 65% of all students and approximately 88% of baccalaureate nursing students who participated in the study were female. Due to the non-uniform gender distribution between the two professions, the apparent difference in cognitive level may not be valid. In the final multivariate model, gender shows a borderline association with CTSR score (p = 0.05), suggesting a degree of influence on the reasoning abilities of the students.

There are some limitations in our study. Students were not randomized to take the CTSR. Voluntary participation may have created a bias while enrolling students in the study. We also experienced difficulty in recruiting healthcare students, even after multiple approaches. As a result, we selected those students who voluntarily agreed to additional learning in an already highly demanding environment. Additionally, we may have introduced a systematic bias in our effort to enroll a similar number of students from both medical and baccalaureate nursing professional programs without accounting for the differences in students' gender dominance in both professions. Lastly, it is important to exercise caution when comparing nursing students with medical students, as they are at different stages in their professional education. According to Piaget's theory of cognitive development, advanced reasoning skills are more likely to be observed in students at higher educational levels. Zhou et al. conducted an in-depth analysis of response versus reasoning on two CTSR questions, examining students from grade 4 through college graduates.[37] Their study found that scientific reasoning develops progressively throughout the years of schooling up to college. However, the variation in scientific reasoning significantly decreases among college students, though some variation still remains.

Conclusion

In conclusion, if we expect our healthcare professionals to avoid cognitive errors in making clinical decisions, we encourage the incorporation of cognition enhancing strategies long before the students enter the professional colleges38 and incorporate the practice of evaluating students' cognitive levels at admission. ■

Author's Contribution

AD, AB, KK, EM - wrote and reviewed the manuscript; MS - reviewed the manuscript. All authors approved the final manuscript.

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