RESEARCH

The Test of Logical Thinking as a Predictor of First-Year Pharmacy Students' Performance in Required First-Year Courses

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Objectives. To investigate the correlation of scores on the Test of Logical Thinking (TOLT) with first-year pharmacy students' performance in selected courses.

Methods. The TOLT was administered to 130 first-year pharmacy students. The examination was administered during the first quarter in a single session.

Results. The TOLT scores correlated with grades earned in Pharmaceutical Calculations, Physical Pharmacy, and Basic Pharmacokinetics courses.

Conclusion. Performance on the TOLT has been correlated to performance in courses that required the ability to use quantitative reasoning to complete required tasks. In the future, it may be possible to recommend remediation, retention, and/or admission based in part on the results from the TOLT.

Keywords: Test of Logical Thinking, critical thinking, assessment, outcomes, quantitative reasoning

INTRODUCTION

It is important to understand the reasons for failure and success in pharmacy school. The North American Pharmacist Licensure Examination (NAPLEX) is used by various state boards of pharmacy to assess an individual's competency to practice pharmacy. Madden and colleagues showed that course failure greatly increased the probability for first time failure on the NAPLEX.¹ In this study, we explored reasons for student success in courses that are the most frequently remediated. Specifically, the Test of Logical Thinking (TOLT) has been correlated with success in selected pharmacy courses involving quantitative reasoning, similar to that encountered in chemistry and beginning college math classes. In the future it may be possible to recommend appropriate admission, retention, and remediation policies based, in part, on students' TOLT scores.

Piaget created a model for cognitive development that has found widespread use in education and psychology.² An accessible discussion of Piaget's model for cognitive development for educators has been published by Wadsworth.³ According to Piaget, cognitive development can be divided into 4 stages:

- (1) Sensio-motor stage (0- 2 years). In this stage, children do not think conceptually.

- (2) Preoperational thought stage (2-7 years). Language is developed in this stage.
- (3) Concrete operations stage (7-11 years). Logical thought to concrete problems occurs.
- (4) Formal operations stage (11-15 years). Logical thought is applied to all classes of problems.

The ages in parentheses are those assigned by Piaget. Achievement of each stage may be earlier or considerably later than indicated above. The transition from concrete to formal reasoning has been of interest to those in secondary and postsecondary education for the past few decades.³⁻⁵ Formal reasoning appears to be an essential component for success in science and engineering.^{6,7}

Although individuals in both stage 3 and stage 4 are able to apply logic to problem solving, individuals who use formal reasoning can apply logic to a much wider variety of problems. Individuals who employ concrete reasoning can only do so to concrete problems of the present. Individuals who employ formal reasoning can consider both hypothetical and complex verbal problems involving the past, present, or future. Formal reasoning allows for the application of general theories to problems.

Specific logical operations that are characteristic of formal reasoning are:

- (1) Proportions
- (2) Separation of variables (conservation of movement)
- (3) Probabilities
- (4) Correlations (<100%)

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(5) Combinatorial reasoning

In the 1980s, Tobin and Capie constructed the TOLT to measure formal reasoning.^{4,5} The test consists of 10 questions to measure formal reasoning ability. Two questions address each of the 5 reasoning modes addressed above. In the first 8 questions, the student is asked to provide the correct answer and the reason that this answer is correct. Both the answer and reason must be correct for the student to receive credit. The last 2 questions involve combinatorial reasoning and require the student to enumerate the possibilities. The score on the TOLT is an integer value between 0 and 10. For each question correctly answered, the student receives 1 point, and for each question with a wrong answer, the student receives 0 points. The TOLT has been used on several occasions to correlate the performance of science and engineering students in secondary and postsecondary schools with their ability to use logical thinking.⁷⁻⁹ In general, performance in science and engineering is correlated with TOLT scores.

In the present study, the relation between the TOLT score and performance in pharmaceutical calculations, physical pharmacy, and basic pharmacokinetics courses was investigated. This study differs from earlier studies using the TOLT in that the student population was older (mean age ~25 years) and the students have been selected twice: once for admission to college and once for admission to pharmacy school. This study compares TOLT scores of first-year pharmacy students with the students' performance in specific courses.

METHODS

The TOLT was administered to 130 first-year pharmacy students at LECOM during their first quarter on campus. Faculty members followed the instructions for administration provided by the test writers. At a minimum, students had completed the prerequisite courses required during the first 2 years of study in college. The class size was 143 students. The results of the TOLT then were compared to the grades these students had achieved in the Pharmaceutical Calculations, Physical Pharmacy, and Basic Pharmacokinetics courses. Each of these courses was completed during the first year of study. This study was approved by the Lake Erie College of Osteopathic Medicine Institutional Review Board (LECOM IRB) by expedited review. The IRB rules dictated that students had to consent in order to participate in the study and could decline to consent at any time. The IRB authorization precluded access to students' Pharmacy College Admission Test (PCAT) scores, which are not required for admission to LECOM, and grade point averages. Analysis of variance (ANOVA) was used to determine

if gender, student age, or course grade was related to TOLT score. The Dunnett and Tukey posthoc tests were used to determine significance.

RESULTS

The TOLT scores of the 130 students ranged from 5 to 9. The average age of the students taking the test was 25 ± 5 years. The youngest students were 20 years old and the oldest student was 52 years old. While not significant, as confirmed by ANOVA, the average age of students with a TOLT score of 5 was 25.6 years, while the average age of students with a TOLT score of 9 was 23.8 years. Nevertheless, age of the students was not a significant factor relating to the TOLT score. Fifty-seven percent of the students taking the TOLT were female. There was no significant difference between TOLT score and gender and the average TOLT scores of each gender were nearly the same.

Question 2 on the TOLT, which concerns proportional reasoning using items only available in integer quantities, was the most frequently missed question. Incorrect responses on this question appear to be why no students attained a score of 10 on the TOLT. Questions concerning control of variables and combinatorial reasoning caused low-scoring students the most difficulty (Figure 1).

Pharmacy courses that involved a significant amount of quantitative reasoning included Pharmaceutical Calculations, Physical Pharmacy, and Pharmaceutical

Figure 1. Average score for each question pair vs TOLT score. There were 2 questions in each question group. If all students answered both questions correctly, then the average would have been 2; if no students were able to answer any of the questions correctly, the score would have been zero. Questions 1 and 2 address proportional reasoning. Questions 3 and 4 concern controlling variables. Questions 5 and 6 address probabilistic reasoning. Questions 7 and 8 concern correlations. Questions 9 and 10 address permutations.

Figure 2. Left – Percent of students earning a grade of A in Physical Pharmacy, Pharmaceutical Calculations and Basic Pharmacokinetics versus TOLT score. Right - Percent of students earning a grade of C or F in the above listed courses versus TOLT score. Grades of A, B, C, and F can be earned.

Calculations. Pharmacy students' performance in these courses vs their TOLT score are presented in Figure 2.

The results in Figure 2 show that performance in Physical Pharmacy, Basic Pharmacokinetics, and Pharmaceutical Calculations was linked to TOLT scores. Students with a TOLT score of 5 or 6 had the greatest probability of receiving a grade of C or F, and simultaneously, the least probability of receiving a grade of A. The TOLT scores for students receiving a grade of A were better than those of students receiving a grade of C or F.

DISCUSSION

The TOLT specifically addresses problem-solving skills and does not consider subject-specific prior knowledge. We do not disagree that portions of the PCAT or SAT might correlate with academic success. The PCAT and SAT address both thinking skills and subject matter familiarity. The TOLT is written in simple language suitable for middle school children. We have no way to address English as a second language. Students entering LECOM must demonstrate a reasonable command of English (written and oral).

Question 2 on the TOLT, which concerns proportional reasoning using items only available in integer quantities, was the most frequently missed question. The high rate of incorrect answers to question 2 is interesting as pharmacists frequently dispense drugs in unit quantities (tablets). The reasons for this result are not known.

The average TOLT score in this study was 7.7. Earlier studies using college students showed mean scores of 6.8,⁶ 5.6,⁷ and 4.4.⁴ The higher mean score reported in this study likely is indicative of the maturity of the pharmacy students and the selection process of the school of pharmacy's admission committee. In the present study, no scores below 5 were observed, whereas in college students, scores ranged from 0-10. The number of high scores (8-10) increased

dramatically between grade 8 (typically age 13 years) and college.⁴

The distribution of TOLT scores (Figure 3) in the present study was compared to those obtained by Tobin and Capie⁴ with high school and college students. Clearly, the pharmacy school admissions process and perhaps maturity eliminate students with very low scores (0-4). Nonetheless, approximately 20% of the pharmacy students in this study had not fully mastered logical thinking skills (TOLT score of 5-6). Approximately, 65 % of the pharmacy students demonstrated the ability to use formal reasoning most of the time (TOLT score of 8-10).

Vasquez and de Angkant correlated TOLT scores to engineering students' performance in basic math and science

Figure 3. The distribution of TOLT scores obtained in this study (LECOM, black bars) to an earlier study by Tobin and Capie that included high school students enrolled in chemistry and physics (gray bars) (N=82) and college students enrolled in science classes (gray stripes).⁴ (N=247). Demographic differences between the high school and beginning college populations studied by Tobin and Capie are unknown. For this reason comparison between the high school and college populations should not be inferred.

classes.⁷ Specifically, TOLT performance was related to failure in algebra, calculus, chemistry, and physics courses.

In the past, several investigators have found correlations between the TOLT score and performance of tasks associated with formal reasoning. The results of this study are consistent with earlier studies in that students with low TOLT scores, in general, do not perform as well in Physical Pharmacy, Pharmaceutical Calculations, and Basic Pharmacokinetics. As stated at the beginning of this paper, failure in Physical Pharmacy correlates with first-time failure on the NAPLEX.¹ The results are also consistent with Piaget's Theory and the earlier study by Miller in that the older and selected population in this study performed better than did beginning college students.¹⁰ Older populations may have had sufficient time for their brains to mature. These individuals also may have been exposed to training involving logical thought. The authors are not aware of a study compiling TOLT scores of adults from the general population. In contrast to the earlier study by Vasquez, the students in our population were generally good at probabilistic thinking but were poor at solving variable control problems.⁷

Factors other than logical thinking contribute to academic success. Some of these qualities might include perseverance, drive, and freedom from social or medical problems.³ Some instructors believe that by incorporating cognitive conflict or surprise into their courses, their students may develop deeper interest in the subject at hand and that in turn will increase their motivation.

CONCLUSION

The TOLT can be used by pharmacy educators as part of an evaluation process to identify at-risk students. Programs for at-risk students that challenge their logical-thinking

abilities could be developed in the future. Furthermore, failure in 1 or more pharmacy school courses by students with high TOLT scores may suggest the presence of issues unrelated to intellectual ability. Different services for this latter group may need to be developed.

We found that the TOLT was a predictor for academic success in pharmacy courses involving quantitative reasoning. We plan to test future classes, thus increasing the population size and perhaps allowing for finer distinctions to be made.

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