Available online at www.sciencedirect.com
ScienceDirect
Currents in Pharmacy Teaching and Learning 8 (2016) 271–278
Currents in Pharmacy Teaching & Learning
http://www.pharmacyteaching.com

Research article

Assessing development in critical thinking: One institution's experience☆

Michael J. Peeters, PharmD, MEd, FCCP, BCPS*, Sai H.S. Boddu, PhD

University of Toledo College of Pharmacy and Pharmaceutical Sciences, Toledo, OH

Abstract

Objective: Enhancing critical and moral thinking are goals of higher education. We sought to examine thinking development within a Doctor of Pharmacy (Pharm.D.) program.
Methods: The California Critical Thinking Skills Test (CCTST), Health Sciences Reasoning Test (HSRT), and the Defining Issues Test (DIT2) were administered to Pharm.D. students over four sessions throughout their didactic studies. Students took tests in their P1 Fall, P1 Spring, P2 Spring, and P3 Spring. While CCTST and HSRT are similar for assessing foundational critical thinking, the DIT2 assesses complex moral thinking. Each thinking test was correlated with academic success by undergraduate and graduate grade-point averages (GPAs).
Results: The CCTST was administered in P1 Fall (20.1 ± 5.0). For HSRT, mean ± S.D. was P1 Spring: 22.7 ± 3.5, P2 Spring: 22.6 ± 4.8, and P3 Spring: 23.8 ± 4.5. After converting P1-CCTST and P2-HSRT scores using user-manual interpretations, there was no difference on paired comparison ($P = 0.22$, 0.1 Cohen's *d*). There was a small difference between P1-HSRT and P3-HSRT ($P < 0.01$, 0.2 Cohen's *d*). Also administered each time, the DIT2 was P1 Fall: 40.4 ± 12.6, P1 Spring: 36.3 ± 13.7, P2 Spring: 44.9 ± 13.6, and P3 Spring: 43.4 ± 15.4. For DIT2, both P1 Fall to P2 Spring and P1 Spring to P3 Spring were significant with small and medium effect-sizes (both $P < 0.01$, 0.4 and 0.5 Cohen's *d* respectively). Importantly, multiple HSRT, and DIT2 assessments correlated with undergraduate and graduate GPAs.
Conclusions: During a Pharm.D. program of study, students developed substantially in moral reasoning though minimally in foundational critical thinking. Both foundational and moral reasoning correlated with academic success. Showing responsiveness to change, the DIT2 appears helpful as a measure of cognitive development for pharmacy education.
© 2016 Elsevier Inc. All rights reserved.

Keywords: Critical thinking; California critical thinking skills test; Health sciences reasoning test; Defining issues test; Assessment; Measurement

Introduction

Development of critical thinking has been adopted universally as an important goal of higher education.[1–4] However, it has also been recognized that there can be considerable variation and confusion in definitions of "critical thinking,"[4] including from pharmacy education.[5,6] While expanded background for thinking definitions and measurement instruments has been recently reviewed for pharmacy education,[6,7] the following is a short summary. There appear to be two major, though different, constructs described as "critical thinking" that have each been studied with promise in pharmacy education[6,7] and other health professions[8]—foundational critical thinking and complex thinking/reasoning, as shown in Figure. Decades ago, these

☆University of Toledo College of Pharmacy and Pharmaceutical Sciences funded the administration of these assessments.

* Corresponding author: Michael J. Peeters, PharmD, MEd, BCPS, FCCP, University of Toledo College of Pharmacy and Pharmaceutical Sciences, 3000 Arlington Ave, Mail Stop 1013, Toledo, OH 43614.

E-mail: michael.peeters@utoledo.edu

http://dx.doi.org/10.1016/j.cptl.2016.02.007
1877-1297/© 2016 Elsevier Inc. All rights reserved.

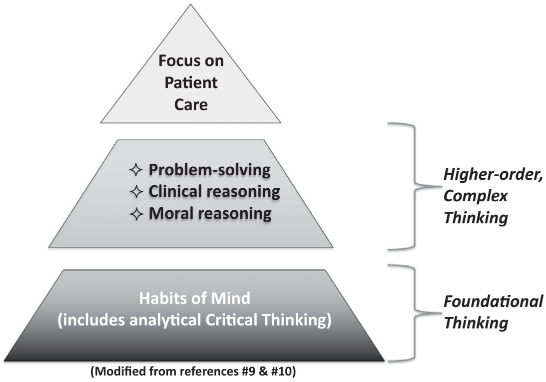

Fig. A cognitive framework for critical and complex thinking[6].

forms of thinking had been described in education with Marzano's Dimensions of Learning model.[9,10]

"Habits of mind" is terminology used within the Center for the Advancement of Pharmacy Education (CAPE) 2013 Educational Outcomes,[11] referring readers to Costa's work for further insight. Costa notes that "critical thinking," while not mention specifically within his habits of mind, coincides with his framework[12]; both Marzano et al.[9] and Costa and Kallick[12] agree that critical thinking is foundational. As a "habit of mind," foundational critical thinking is analytical and involves interpretation or analysis followed by evaluation or judgment.[4] Meanwhile, complex thinking may better be termed problem-solving or clinical reasoning. Following the American Philosophical Association's definition of critical thinking,[13] the California Critical Thinking Skills Test (CCTST) and its more recent extension, the Health Sciences Reasoning Test (HSRT), quantify one conception of foundational critical thinking.

While there is a foundational need for critical thinking, sound thinkers require more complex thinking as well. The Defining Issues Test version 2 (DIT2) quantifies a complex, cognitive-moral perspective to thinking.[14] Importantly, the DIT2 has also been associated with physician and pharmacist professionalism[15,16]; its use in assessment has been recommended for pharmacy education at multiple times.[16–18]

Methods

Setting

The University of Toledo is a comprehensive public institution and includes an academic medical center. The college of pharmacy is a 2 + 4 Doctor of Pharmacy (Pharm.D.) program, where the first two years of the Pharm.D. are considered undergraduate coursework while the remaining two years are graduate-level coursework. While undergoing future changes, at the time of this investigation the curriculum was mainly separate lecture-based basic science and therapeutic course-blocks, with some case-based coursework. This study followed students from the 2015 and 2016 Pharm.D. classes through their didactic first- to third-years. This investigation received the University of Toledo's IRB approval.

Because one of the cognitive development instruments used in this study (i.e., DIT2) is a measure of ethical reasoning, brief mention of that ethics curriculum is needed; this content is explained in more detail elsewhere.[19] In short, "professionalism and ethics" is a longitudinal module throughout the first- to third-year of professional study. Each semester, students build on content from prior material. Ethics, introduced as the four biomedical principles,[20] is a framework to approach pharmacy practice ethical issues. Students reflected on and discussed a number of ethical applications to pharmacy practice. The majority of these are within students' first-year of Pharm.D. study. Within the module, there is no explicit mention or discussion of Kohlberg's model of moral reasoning (which was foundational for initial development of the DIT2 instrument[21]).

Design

This was a longitudinal cohort research study design that followed two class years of Pharm.D. students from their first through third professional years (P1–P3). To measure change, a longitudinal research study design has been championed.[22] The large Wabash National Study assessed thinking development (foundational critical thinking and complex thinking) among numerous undergraduates at liberal arts colleges; it used a longitudinal research study design.[22] Each entering Pharm.D. class was randomly divided into a Group A and a Group B. The randomization first stratified students into sections based on introductory pharmacy practice experiences scheduling, pharmacy practice experience, and future practice setting interests; second was to alternate between tests in each lab section wherein an equal number of students took each test.

Group A took the CCTST in Fall semester of their first-year, the DIT2 in spring semester of their first-year, the HSRT in spring of their second year, and the DIT2 in the spring of their third year (Table 1). At the same time, Group B did almost the opposite (Table 1). Given that there were roughly two years between repeat administrations of any single version of thinking test used in this study, a student's recall of any instrument's specific content seemed very

Table 1
Critical thinking assessment administration design overview for each Pharm.D. class

Group	P1 Fall	P1 Spring	P2 Spring	P3 Spring
A (half of class)	CCTST	DIT2	HSRT	DIT2
B (half of class)	DIT2	HSRT	DIT2	HSRT

CCTST, California Critical Thinking Skills Test; DIT2, Defining Issues Test, Version 2; HSRT, Health Sciences Reasoning Test.
Note: Only paired significance testing was done (Group A or Group B); cross-sectional testing between groups was avoided (Group A vs. Group B).

Table 2
Critical thinking assessment ranges and norms

(A) Defining issues test (version 2) N2-score norms[23]

Education level	Mean	Standard deviation	Number of subjects
Grade 10–12	31.0	14.8	2284
Vocational/technical/junior college	27.2	14.4	986
Undergraduate	34.8	15.5	32,974
Graduate	41.3	14.6	15,494

(B) California critical thinking skills test interpretations and norms[24]

	Critical thinking ability spectrum				
Interpretation	Not manifested	Weak	Moderate	Strong	Superior
34-item overall score	0–7	8–12	13–18	19–23	24 or higher
Junior college (%)	6	28	44	15	7
Undergraduate (%)	3	16	41	25	15
Graduate (%)	1	8	31	25	35
Health sciences undergraduate (%)	1	7	34	32	25
Health sciences graduates (%)	1	4	23	33	38

(C) Health sciences reasoning test interpretations and norms[25]

	Critical thinking ability spectrum				
Interpretation	Not manifested	Weak	Moderate	Strong	Superior
33-item Overall score	0–14	Not applicable	15–20	21–25	26 or higher
Health sciences undergraduates (%)	8		40	41	11
Health sciences graduates (%)	10		28	38	24

Note: N2-score range is 1–95.

unlikely. Furthermore, in this research study design, each student only took one test at each administration time period, which was a much lower test-taking burden to students than taking two thinking tests at each time period (e.g., limiting test-burden for students was a major issue within our assessment design).

To measure development, students' longitudinal scores were only compared individually; each student's initial test score was matched to their later test score. No cross-sectional comparisons were done between Group A and Group B. Four paired comparisons were planned. First, because students in Group A took the CCTST initially in their P1 Fall, comparison to their P2 Spring HSRT scores were interpreted and recoded for critical thinking ability level, Table 2; this comparison was less-than-ideal (unlike using the same test on both occasions), but with a very high correlations between the instrument scores, it could be viewed as preliminary. The CCTST was initially used in P1 Fall because it was unsure whether, at Pharm.D. program entry, students' limited prior health care exposure would affect how they performed on HSRT items that are situated within health care problems. Second, for students from Group A who took the DIT2 in P1 Spring, those scores would be compared to their result from P3 Spring. Third, for students in Group B who took the DIT2 in P1 Fall, this score would be compared to their score on the DIT2 in P2 Spring. Fourth, comparison in Group B would be done between each student's P1 Spring HSRT and P3 Spring HSRT scores.

Instruments

Noted previously as promising thinking assessments for pharmacy education,[6–8] the CCTST, HSRT, and DIT2 were used in this investigation. To evaluate critical thinking development, these three thinking instruments were administered longitudinally within the University of Toledo College of Pharmacy and Pharmaceutical Sciences assessment program. Looking at each test, the CCTST/HSRT and DIT2 appeared different. The CCTST and HSRT have straightforward, multiple-choice questions (34 questions and 33 questions, respectively) and appear quite similar to one another for assessing foundational critical thinking. Meanwhile, the DIT2 has five cases, asks the test taker for an opinion on what to ethically do in each case, and assesses complex cognitive-moral thinking. Scoring for the DIT2 is also more complicated, though using and reporting the N2-score is recommended for professional and graduate

Table 3
Test results from two Pharm.D. cohorts

Test	Test group	Number of subjects	Administration times			
			P1 Fall[a]	P1 Spring[a]	P2 Spring[a]	P3 Spring[a]
CCTST/HSRT	A/A	96/96	20.1 (5.0)[b]/–	–/–	–/22.6 (4.8)[b]	–/–
DIT2[c]	A	86	–	36.3 (13.7)[d]	–	43.4 (15.4)[d]
DIT2[c]	B	81	40.4 (12.6)[e]	–	44.9 (13.6)[e]	–
HSRT	B	89	–	22.7 (3.5)[f]	–	23.8 (4.5)[f]

CCTST, california critical thinking skills test; DIT2, defining issues test-version 2; HSRT, health sciences reasoning test, P1, Pharm.D. year 1, p2, Pharm.D. year 2, P3, Pharm.D. year 3.

[a] Mean (standard deviation).

[b] $P = 0.22$; 0.1 [trivial] Cohen’s d effect-size;[33] compared only after converting to critical thinking interpretations (moderate, strong, superior; interpretations italized, and score ranges in Table 2).

[c] N2-scores reported.

[d] $P < 0.01$; 0.5 [medium] Cohen's d effect-size.[33]

[e] $P < 0.01$; 0.4 [small] Cohen's d effect-size.[33]

[f] $P < 0.01$; 0.2 [small] Cohen's d effect-size.[33]

programs.[26] The N2-score range is between 1 and 95. The three panels of Table 2 give norms and interpretations for each of the three instruments used; more details can be found in a review for pharmacy education[6] or each test's user manual.[24,25,27]

Statistical analysis

To measure thinking development with each assessment, two measured scores from each student were compared for statistical significance using a paired t-test (SPSS® version 19 for Mac, Armonk, NY). An instrument needs to be responsive to change, which is a characteristic outside of other standard psychometric evidence for reliability and validity.[28,29] It is important to note, only longitudinal statistical comparisons were done, also noted in Table 1. Similar to prior pharmacy[30] and nursing[31] research reports using the CCTST and DIT2, students of higher and lower ability were compared. Based on scores from the first test, development among students in the upper-half were compared to students scoring in the lower-half using an unpaired t-test. Additionally, scores on the thinking assessments were correlated with academic success indicators of undergraduate and graduate grade-point averages (GPAs). For our 2 + 4 program, undergraduate GPA included two pre-Pharm.D. years and the first two Pharm.D. years, while the graduate GPA was from the final two Pharm.D. years.

As opposed to analyzing only statistical significance, practical significance was evaluated in two ways.[32] First, standardized effect-sizes were calculated using Cohen’s d (http://www.uccs.edu/~lbecker) and interpreted using Cohen's recommended general categories (small, medium, and large).[33] Second, the standard error of measurement (SEM) was used as a distribution-based method to determine a minimal clinically important difference.[34,35] While the test developer/scorer for the CCTST and HSRT does not routinely report internal consistency, we assumed these standardized tests would be ~0.75; a similar value has been suggested from CCTST use in nursing[36] and the CCTST user manual.[24] The SEM (standard deviation times the square-root of one minus reliability[37]) would be 0.5 times the standard deviation, which equals the same as a Cohen's d of 0.5.[33] Thus, a medium effect-size by Cohen’s d would suggest a minimal clinically important difference and practically significant result herein.

Furthermore, insight into individual student progress was also ascertained. While all students in Group A or Group B were compared as a group, individual variation among students was also analyzed. For practical significance among these individual differences, the difference in each student's scores was assessed for a clinically important difference using the pooled (i.e., average) SEM from those test administration results. Some students should display developmental improvement beyond the SEM, while others may not change appreciably and still others may diminish between the test occasions.

Results

As in Table 3, the CTTST was administered to 96 students in P1 Fall and was 20.1 ± 5.0 (mean ± standard deviation). Because some students either failed coursework, or were removed by external scoring for inconsistent DIT2 responses to different cases within, the number of students for paired comparison differed with each test. At the beginning of the first-year of this Pharm.D. program, there were 112 students in the Class of 2015 and 108 in the Class of 2016. For HSRT and DIT2, results are also in Table 3.

Four paired comparisons were made for thinking development, with two for each of Group A and Group B. First, Group A's P1 Fall CCTST and P2 Spring HSRT were compared. These tests have not been equated with one another and their raw scores should not simply be compared. As specified in Table 2, CCTST and HSRT scores were transformed into levels of critical thinking ability defined in the user manuals.[24,25] These transformed critical thinking ability interpretations were compared between the CCTST administration and the HSRT administration. Because the goal was to compare an administration of the CCTST to the HSRT, Pearson correlations were first examined among the same students and different pharmacy students. Results were substantial between tests (P1F-CCTST to P2S-HSRT $r = 0.7$, $P < 0.01$). Comparing the interpretation of CCTST with the interpretation from HSRT, no statistical difference was found when assessing development with these similar critical thinking tests [$P = 0.22$, 0.1 Cohen's d (trivial effect-size)]. Additionally, no significant difference was found for the upper-half versus lower-half comparison of the CCTST ($P = 0.17$).

Second, Group A's DIT2 P1 Spring to P3 Spring was statistically significant with a medium effect-size ($P < 0.01$, 0.5 Cohen's d); however, there was no statistical difference with upper-half versus lower-half comparison, and a small effect-size between ($P = 0.09$, 0.4 Cohen's d).

Third, the paired DIT2 results for Group B's P1 Fall to P2 Spring were statistically significant with a small effect-size found ($P < 0.01$, 0.4 Cohen's d). Comparing upper-half versus lower-half on gain in DIT2 from P1 Fall to P2 Spring, independent t-test comparison was statistically significant, with a large effect-size between ($P < 0.01$, 0.8 Cohen's d).

Fourth, Group B's HSRT comparison between P1 Spring and P3 Spring had similar means, was statistically significant, though had a small effect-size ($P < 0.01$, 0.2 Cohen's d). Comparison of upper-half and lower-half HSRT scores was statistically significant, though with a trivial effect-size between ($P = 0.02$, 0.1 Cohen's d).

While entire Group A and entire Group B were compared, Table 4 also shows individual variation in development among students on the test administrations. For all three tests, some students had developmental improvement beyond the SEM, while others did not appreciably change and still others diminished between the test occasions.

Table 5 shows correlations and effect-sizes for the CCTST, HSRT, and DIT2 on undergraduate and graduate grade-point averages. Neither P1 Fall test was statistically significant in correlation to either GPA. Except for P1 Fall assessments, most other correlations were statistically significant for at least one GPA, while the P1 Spring HSRT was substantially significant for both GPAs, with medium and large effect-sizes.

Discussion

Within the current cohorts, the DIT2 changed substantially with education. This is similar to other reports in K-12 education[38] and higher education.[39,40] It appears to be responsive measure of moral cognitive development. Compared to other variables that have been studied for development with education, the DIT2 has shown some of the most dramatic longitudinal gains of cognitive growth.[26]

Our assessments of foundational critical thinking showed little development. Between the spring of the first year and the end of didactics in the third year, a small statistical gain was detected using the HSRT; the practical significance, however, is questionable (i.e., Cohen's $d < 0.5$). Based on critical thinking ability interpretation estimates, as in Table 2, the CCTST–HSRT did not change. Teaching foundational critical thinking takes explicit, deliberate work. One higher education study concluded that many instructors think that they are teaching critical thinking in their courses, although few do[41]; of those who do teach it, foundational critical thiking was most often an explicit learning objective of their course, where specific, focused instruction of critical thinking was provided. In that study, it was also noteworthy that many faculty members could not adequately define critical thinking. In fact, in revising the widely-known Bloom's Taxonomy, Krathwohl[42] introduced the term "understanding," of which faculty members seemed to share a similar concept. He decided, however, not to include "critical thinking," as

Table 4
Development for individual students in multiple Pharm.D. classes

Test	Test group	Number of subjects	Development	
			SEM from pooled SD	Students improved? (gain/same/loss)[a]
CCTST	A	96	N/A	26%/57%/17%[b]
HSRT	A	96		
DIT2[c]	A	86	7.3	45%/45%/10%
HSRT	B	89	2.0	23%/68%/9%
DIT2[c]	B	81	6.8	40%/45%/15%

CCTST, California Critical Thinking Skills Test; DIT2, Defining Issues Test-version 2; HSRT, Health Sciences Reasoning Test; N/A, not applicable; SD, standard deviation; SEM, standard error of measurement.[32,37]

[a] *Gain* > + 1SEM, *same* within ± 1SEM, and *loss* <−1 SEM.

[b] Based on conversion of CCTST and HSRT scores to interpretation (i.e., Table 2), and then compared.

[c] N2-scores reported.

Table 5
Correlation of each critical thinking test to grade-point averages

Critical thinking test		Undergraduate GPA[a]			Graduate GPA[b]		
Term	Test	Pearson r (effect size)	Effect-size interpret[c]	*P* value	Pearson r (effect size)	Effect-size interpret[c]	*P* value
P1 Fall	**CCTST**	0.13	Small	nss	0.28	Small	nss
	DIT2	0.03	Trivial	nss	0.12	Small	nss
P1 Spring	**HSRT**	*0.33*	***Medium***	*0.05*	*0.51*	***Large***	*<0.01*
	DIT2	0.18	Small	nss	*0.34*	***Medium***	*0.03*
P2 Spring	**HSRT**	0.24	Small	nss	*0.31*	***Medium***	*0.04*
	DIT2	0.10	Small	nss	*0.48*	***Medium***	*<0.01*
P3 Spring	**HSRT**	–	–	–	*0.52*	***Large***	*<0.01*
	DIT2	–	–	–	*0.38*	***Medium***	*0.01*

Note: Bold and italicized effect-size interpretation text to denote practical significance evidence.
CCTST, California Critical Thinking Skills Test; DIT2, Defining Issues Test-version 2; HSRT, Health Sciences Reasoning Test; GPA, grade-point average; nss, not statistically significant; P1, Pharm.D. year 1; P2, Pharm.D. year 2; P3, Pharm.D. year 3.
[a] Undergraduate GPA includes first two years of Pharm.D.
[b] Graduate GPA is for last 2 years of Pharm.D.
[c] Effect-size interpretations:[33] trivial ($r < 0.1$), small ($r = 0.10$), medium ($r = 0.30$), and large ($r = 0.50$).

educators did not seem to share a similar definition for this term.

From a psychometric standpoint, our lack of later effect with the HSRT may have come from the lack of test difficulty and resulting restricted scoring range. In general, Pharm.D. students tend to score very well on this exam (Dee August, senior psychometrician at Insight Assessment, email communication May 8, 2014). Thus, pharmacy students would cluster as "strong" or "superior" critical thinkers—more than half of the instrument's scoring range would not be used (i.e., weak or moderate critical thinking). Therefore, to show a meaningful difference, the test must become even more challenging by extending its scale toward higher difficulty. The CCT-G835 does just this and may be more appropriate for foundational critical thinking measurement in pharmacy education (Dee August, Insight Assessment, email communication May 8, 2014). An alternative method is to switch focus from attempting to assess foundational critical thinking toward assessing complex thinking (i.e., cognitive-moral development) as recommended by pharmacy education leaders.[16–18]

As expected following a prior reviews of critical thinking in the pharmacy education literature,[5,6] these different thinking assessments have shown dissimilar results. While the CCTST and HSRT measured foundational critical thinking, the DIT2 measured more complex thinking. Our results confirm a theoretical framework wherein "critical thinking" relates to a foundational, analytical habit of mind while higher-order, complex thinking (which some educators may mis-term "critical thinking") involves problem-solving, clinical reasoning, and other complex reasoning.[9,10] As such, habits of mind as recommended by the CAPE 2013 Educational Outcomes[11] (which include analytical critical thinking within the habits[9,12]) should be cultivated early in K-12 education, and much in preparation for higher education. Once students have already shown academic success within the college setting, trying to develop students' foundational critical thinking further within Pharm.D. education may not be as important. Success in pre-pharmacy college coursework may already be selecting for strong foundational critical thinking skill. It did not appreciably develop further during this Pharm.D. program; it may not have been adequately taught for improving strong critical thinkers, but should it be taught further at this point anyways?

Kelsch and Freisener[43] noted how the critical thinking-specific HSRT did not add meaningful information to their pharmacy admission process. Furthermore, Cox and McLaughlin[44] showed a limited correlation of HSRT with later academic success indicators and suggested a limitation on any associations being meaningful. Both foundational and complex thinking correlated with academic success indicators in this study; in fact, the foundational HSRT correlations appeared stronger than complex DIT2 correlations. Foundational critical thinking has good evidence when correlated with academic success among Pharm.D. students.[3,6]

This study demonstrated little development in foundational critical thinking. Between this study and evidence cited in the introduction, it would suggest little substantial teaching and learning of this is being done in this Pharm.D. program. Importantly, it should be noted that critical thinking was strong or superior in most of our pharmacy students anyways. Knowing this, there would appear to be diminishing or inconsequential gains in trying to teach it further. However, complex thinking holds promise and consistently developed in more than one student cohort within this investigation. It grew most among students who scored lowest and needed it the most. Additionally, and related to assessment methodology, the strong association shown between P1 Spring within this investigation tests with both undergraduate and graduate GPAs would suggest that waiting until students are well into a Pharm.D. program before critical thinking testing would correlate strongly with academic success.

Moral reasoning is a sound indictor that has shown improvement with college education.[20,23,26,27,45] Some professions, however, have discussed a lack of moral reasoning development,[46,47] while pharmacy education has shown conflicting results.[7] Similar to critical thinking, this complex thinking does not necessarily grow automatically, though it can improve from dedicated educational initiatives. Barriers have been discussed toward improving moral reasoning for pharmacy education.[16] Our analysis showed that the DIT2 can successfully be used for further program assessment. Extending this, its use over multiple administrations may, by itself, foster further development.[48] Clearly, the DIT2's association with professionalism and subsequent professional development is a promising avenue for further investigation in pharmacy education.[19,49]

Based on these results, our recommendation for our college of pharmacy is to avoid using the CCTST and HSRT. Foundational critical thinking was strong or superior in most of our students, and (presumably) admission variables of pre-pharmacy GPA and PCAT are helping in the selection of students with a robust critical thinking foundation. Meanwhile the DIT2 assesses complex thinking, granted only one facet of these complex thinking skills. Similar to periodically monitoring a patient's pulse, we recommend that our college periodically measure development of complex thinking with the DIT2, making sure that we continue this development.

Limitations

This current investigation was most limited by sampling—that is, these assessments are from one institution, and the results differ from some prior studies specifically within pharmacy education.[7] However, in a recent meta-analysis of health professions, pharmacy differed from other health professions in pooled effects for moral reasoning.[8] Our results were similar to professions other than pharmacy and suggest that pharmacy education can develop complex thinking as well.

Conclusion

Two cohorts of Pharm.D. students improved in their complex thinking, though their foundational critical thinking did not improve substantially. Interestingly, students with lowest complex thinking initially appeared to benefit most. Both the HSRT and DIT2 correlated significantly with academic success measures (undergraduate and graduate GPAs). This appears to be the first pharmacy study to report a substantial positive effect-size with the DIT2. Our analysis demonstrates that the DIT2 could be helpful in program assessment for pharmacy education.

Conflicts of interest

None.

Acknowledgments

We thank Dr. Sharrel Pinto for her assistance in planning the longitudinal design for this approach using multiple critical thinking tests, and Dr. Paul Erhardt for critically reviewing this article.

References

[1]. Roska J, Arum R. The state of undergraduate learning. *Change*. 2011;43(2):35–38.
[2]. Arum R, Roksa J. *Academically Adrift: Limited Learning on College Campuses*. Chicago, IL: The University of Chicago Press; 2011.
[3]. Papp KK, Huang GC, Lauzon Clabo LM, et al. Milestones of critical thinking: a developmental model for medicine and nursing. *Acad Med*. 2014;89(5):715–720.
[4]. Nilson LB. Unlocking the mystery of critical thinking. *Fac Focus*. 2014. http://www.facultyfocus.com/articles/instructional-design/unlocking-mystery-critical-thinking. Accessed March 8, 2016.
[5]. Oderda GM, Zavod RM, Carter JT, et al. An environmental scan of the status of critical thinking and problem solving skills in colleges/schools of pharmacy: report of the 2009–2010 academic affairs standing committee. *Am J Pharm Educ*. 2010;74(10): Article S6.
[6]. Peeters MJ, Zitko KL, Schmude KA. Development of critical thinking in pharmacy education. *Innov Pharm*. 2016;7(1): Article 5.
[7]. Peeters MJ, Zitko KL, Vaidya VA. Critical thinking development in pharmacy education: a meta-analysis. *Innov Pharm*. 2016;7(1): Article 10.
[8]. Reale M, Witt B, Riche D, Baker W, Peeters MJ. Development of critical thinking among health profession students: a meta-analysis. *Am J Pharm Educ*. 2015;79(5): Article S4.
[9]. Marzano RJ, Pickering D, McTighe J. *Assessing Student Outcomes: Performance Assessment Using the Dimensions of Learning Model*. Alexandria, VA: Association for Supervision and Curriculum Development; 1993.
[10]. Brennan RL. *Educational Measurement*. Westport, CT: American Council on Education (with National Council on Measurement in Education); 391 [Table 11.1].
[11]. Medina MS, Plaza CM, Stowe CD, et al. Center for the Advancement of Pharmacy Education 2013 educational outcomes. *Am J Pharm Educ*. 2013;77(8): Article 162.
[12]. Costa AL, Kallick B. *Discovering and Exploring Habits of Mind*. Alexandria VA: Association for Supervision and Curriculum Development; 2000.

[13]. Facione PA. *Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction*. Millbrae, CA: The California Academic Press; 1990.
[14]. Rest JR, Narvaez D. *Moral Development in the Professions*. Hillsdale, NJ: Lawrence Erlbaum Associates; 1994.
[15]. Baldwin DC, Self DJ. The assessment of moral reasoning and professionalism in medical education and practice. In: Stern DT, ed. *Measuring Medical Professionalism*. New York, NY: Oxford University Press; 2006:75–93.
[16]. Duncan-Hewitt W. The development of a professional: reinterpretation of the professionalization problem from the perspective of cognitive/moral development. *Am J Pharm Educ*. 2005;69(1): Article 6.
[17]. Wells BG, Beck DE, Draugalis JR, et al. Report of the 2007–2008 Argus Commission: what future awaits beyond pharmaceutical care? *Am J Pharm Educ*. 2008;72(supp): Article S8.
[18]. Duncan W, Soltis R, Sicat B, et al. *Recommendations of COF/COD Task Force on Cognitive and Moral Development*. 〈http://www.aacp.org/governance/councilfaculties/Documents/July2012COFBusinessMeetingMinutes.pdf〉. Accessed March 13, 2016.
[19]. Peeters MJ, Vaidya VA. A mixed-methods analysis in assessing students' professional development: using an assessment for learning approach. *Am J Pharm Educ*. 2016 [accepted].
[20]. Beauchamp TL, Childress JF. *Principles of Biomedical Ethics*, 5th ed, New York, NY: Oxford University Press; 2001.
[21]. Rest JR. *Moral Development*. New York, NY: Praeger Publishing; 1986.
[22]. Seifert TA, Pascarella ET, Erkel SI, Goodman KM. The importance of longitudinal pretest–posttest designs in estimating college impact. *New Directions for Institutional Research*. 2010;2010(S2):5–16.
[23]. Dong Y. Norms for DIT2: From 2005 to 2009. *Center for the Study of Ethical Development*. Retrieved from 〈http://ethicaldevelopment.ua.edu/files/2014/03/Norms-for-DIT2.pdf〉. Accessed March 13, 2016.
[24]. Insight Assessment. *California Critical Thinking Skills Test User Manual*. San Jose, CA: California Academic Press; 2015.
[25]. Insight Assessment. Health Sciences Reasoning Test User Manual. San Jose, CA: California Academic Press; 2015.
[26]. Thoma SJ, Dong Y. The defining issues test of moral judgment. *Behav Develop Bull*. 2014;19(3):55–61.
[27]. Bebeau MJ, Thoma SJ. *Guide for DIT-2*. Minneapolis, MN: Center for the Study of Ethical Development; 2003.
[28]. Kirshner B, Guyatt G. A methodological framework for assessing health indices. *J Chron Dis*. 1985;38(1):27–36.
[29]. Guyatt G, Walter S, Norman G. Measuring change over time: assessing the usefulness of evaluative instruments. *J Chron Dis*. 1987;40(2):171–178.
[30]. Phillips CR, Chesnut RJ, Rospond RM. The California critical thinking instruments for benchmarking, program assessment, and directing curricular change. *Am J Pharm Educ*. 2004;68(4): Article 101.
[31]. Duckett L, Rowan M, Ryden M, et al. Progress in the moral reasoning of baccalaureate nursing students between program entry and exit. *Nurs Res*. 1997;48(4):222–229.
[32]. Peeters MJ. Practical significance: moving beyond statistical significance. *Curr Pharm Teach Learn*. 2016;8(1):83–89.
[33]. Cohen J. A power primer. *Psychol Bull*. 1992;112(1): 155–159.
[34]. Jaeschke R, Singer J, Guyatt GH. Measurement of health status: ascertaining the minimal clinically important difference. *Control Clin Trials*. 1989;10(4):407–415.
[35]. Norman GR, Sridhar FG, Guyatt GH, Walter SD. Realtion of distribution- and anchor-based approaches in interpretation of changes in health-related quality of life. *Med Care*. 2001;39 (10):1039–1047.
[36]. Adams MH, Whitlow JF, Stover LM, Johnson KW. Critical thinking as an educational outcome: an evaluation of current tools of measurement. *Nurse Educ*. 1996;21(3):23–32.
[37]. Peeters MJ, Beltyukova SA, Martin BA. Educational testing and validity of conclusions in the scholarship of teaching and learning. *Am J Pharm Educ*. 2013;77(9): Article 186.
[38]. Hill CJ, Bloom HS, Black AR, Lipsey MW. Empirical benchmarks for interpreting effect sizes in research. *Child Dev Perspect*. 2008;2(3):172–177.
[39]. Blaich C, Wise K. *The Wabash National Study—The Impact of Teaching Practices And Institutional Condition on Student Growth*. Annual Meeting of the American Educational Research Association, New Orleans, LA. 〈http://static1.1.sqspcdn.com/static/f/333946/12586532/1307467024793/Wabash-Study-Student-Growth_Blaich-Wise_AERA-2011.pdf?token=Ye3DJdZYipSlrlu4qrKfQPFUtAQ%3D〉; 2011 Accessed March 13, 2016.
[40]. Pascarella ET, Blaich C, Martin G, Hanson JM. How robust are the findings of academically adrift? *Change*. 2011;43(3): 20–24.
[41]. Paul R, Elder L, Bartell T. *Study of 38 Public Universities and 28 Private Universities to Determine Faculty Emphasis on Critical Thinking in Instruction*. Foundation for Critical Thinking. 〈http://www.criticalthinking.org/pages/study-of-38-public-universities-and-28-private-universities-to-determine-faculty-emphasis-on-critical-thinking-in-instruction/598〉;1997 Accessed March 13, 2016.
[42]. Krathwohl DR. A revision of Bloom's Taxonomy: an overview. *Theory Pract*. 2002;41(4):212–218.
[43]. Kelsch MP, Freisener DL. The health sciences reasoning test in the pharmacy admissions process. *Am J Pharm Educ*. 2014;78(1): Article 9.
[44]. Cox WC, McLaughlin JE. Association of health sciences reasoning test scores with academic and experiential performance. *Am J Pharm Educ*. 2014;78(4): Article 73.
[45]. Rest JR. Why does college promote development in moral judgement? *J Moral Educ*. 1988;17(3):183–194.
[46]. Self DJ, Baldwin DC. Does medical education inhibit the development of moral reasoning in medical students? A cross-sectional study. *Acad Med*. 1998;73(supp 10): S91–S93.
[47]. Hartwell S. Moral growth or moral angst? A clinical approach. *Clin Law Rev*. 2004;11:115.
[48]. Mayhew MJ, Pascarella ET, Trolian T, Selznick B. Measurements matter: taking the DIT-2 multiple times and college students' moral reasoning development. *Res High Educ*. 2015;56(4):378–396.
[49]. Vaidya VA, Peeters MJ. Assessing professional development (Standard 4): the University of Toledo's experience. *Am J Pharm Educ*. 2015;79(5): Article S4 [abstract].