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Research Note

The impact of team-based learning on the critical thinking skills of pharmacy students

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ABSTRACT

Introduction: Critical thinking is an important ability for pharmacists, but few studies have found improvements in pharmacy student critical thinking skills as a consequence of their education. Team-based learning (TBL) is an active learning strategy that encourages students to think critically to solve problems. The purpose of this study was to evaluate the impact of TBL on the critical thinking skills of pharmacy students.
Methods: One hundred ninety students from the first two cohorts at a pharmacy school were invited to participate. The Health Science Reasoning Test (HSRT) was administered prior to the first semester and after two years of the TBL-based pharmacy curriculum. Student's *t*-test was used for a pairwise analysis along with Welch's *t*-test for unequal variances when comparing HSRT score modulation.
Results: There was an overall increase in mean HSRT score. However, some participants (29%) with initially higher mean HSRT scores did not demonstrate an increase. Nearly all (99%) participants demonstrated improvements of one of the eight domains of critical thinking evaluated in the HSRT. This corresponded with an improvement in score of the majority of participants ($n = 115$).
Conclusion: This study provides evidence that TBL improves critical thinking skills. More research is needed to identify the specific aspects of TBL that influence critical thinking.

Introduction

Critical thinking is an acquired and evolving ability that develops independently within each of us.[1] Critical thinking is defined by the Association of American Colleges and Universities as "a habit of mind characterized by the comprehensive exploration of issues, ideas, artifacts, and events before accepting or formulating an opinion or conclusion."[2] Critical thinking is an essential skill for pharmacy students' development and transition into professional pharmacy.[3,4] Moreover, strong critical thinking skills are an indicator of student success in pharmacy school.[5] The purpose of this study is to evaluate the pedagogy of team-based learning (TBL) on critical thinking skills of pharmacy students. To do this, a longitudinal analysis using the Health Sciences Reasoning Test (HSRT) was performed and results analyzed.

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The Accreditation Council for Pharmacy Education Standards 2016 require documentation that reports student achievement of critical thinking capabilities.[6] Pharmacy students have demonstrated improved critical thinking skills with formative feedback and reflective self-learning.[7] Research suggests that critical thinking can be improved by a contextual environment of thoughtful learning (i.e. integration), guidance and support to independence (i.e. scaffolding), sensory observation of cognitive operations (i.e. model behavior), and open question feedback (i.e. challenging assumptions).[8,9] Optimal strategies that consistently integrate these components into classroom instruction are unclear. However, TBL may be a pedagogical strategy that provides ample opportunities to develop critical thinking skills through problem solving in teams.

In the classroom, TBL involves three distinct phases: preparation, readiness assurance process (RAP), and application.[10] During the preparation phase, students study material prior to class that has been carefully selected by instructors to align with leaning objectives. This provides the scaffolding needed for class preparation. Next, the RAP involves an individual readiness assurance test (iRAT) to hold students accountable for their preparation. Then, the members of the team collectively take the same test, the team readiness assurance test (tRAT), often using immediate feedback assessment technique (IF-AT) forms.[11] IF-AT forms by Epstein Educational Enterprises are scratch-off cards that reveal a star for correct answers. By administering the test in this fashion several advantages are gained toward critical thinking: (1) completing the same test as a team enables students to re-visit questions and arrive at a decision together, (2) defending individual choices and evaluating options involves higher level thinking, and (3) the immediate feedback provided by IF-AT forms provides an additional opportunity to evaluate and discuss options. If students identify an incorrect answer, they are then able to try again. This allows them to re-evaluate their discussion and once again requires higher-order thinking skills.[12,13] The final phase of TBL involves applying core concepts to solve significant problems (application exercises) in teams. Application exercises require students to select the 'best' answer from a selection of possibilities, an approach that, by design, incorporates critical thinking skills.

Key elements to critical thinking (i.e. integration, scaffolding, model behavior, challenging assumptions) are therefore encouraged throughout the TBL process. McInerney and Fink[14] found that student perceptions of their critical thinking skills improved in a microbiology course that utilized TBL. A study by Bleske et al.[15] comparing TBL and lecture found that student confidence and learning outcomes were significantly improved with TBL. TBL may be an effective modality to augment critical thinking skills throughout pharmacy education. Outcomes assessment is a necessary tool to establish the effectiveness of techniques used to teach critical thinking skills in medical education.[16,17] As yet, no known published studies have been conducted that compare critical thinking skills by outcomes assessment, prior to and following longitudinal TBL instruction.

One mechanism to assess critical thinking skills is through the use of the HSRT. The HSRT is a critical thinking test that is "specifically designed to assess the critical thinking skills of health science students."[18] The HSRT is comprised of multiple-choice questions that range in difficulty and complexity. It assesses critical thinking ability in eight domains: interpretation, analysis, inference, explanation, evaluation, induction, numeracy, and deduction. Higher percentile scores indicate higher critical thinking ability compared to other health sciences students. Furthermore, the HSRT has been shown to be a predictor of performance on the Pharmacy Curriculum Outcomes Assessment.[19] A meta-analysis of changes in critical thinking skills over time revealed that students in a variety of health professions, including pharmacy, did not show any improvement on the HSRT.[20] Other longitudinal studies that assessed changes in pharmacy student critical thinking skills have yielded mixed results.[21,22] A recent study of pharmacy student critical thinking skills following a course in critical thinking did not find any differences in overall, percentile, or sub-domain scores on the HSRT, except for an improvement in analysis and lower scores in induction.[23] Miller[21] found that pharmacy student scores on the California Critical Thinking Dispositions Inventory (CCTDI) increased over the course of the program. However, Cisneros[22] discovered nominal improvement with pharmacy students after one academic year on the CCTDI and the California Critical Thinking Skills Test (CCTST). Although it is difficult to ascertain outcome variances between these studies, they indicate that traditional pharmacy education alone is unlikely to improve critical thinking ability and that teaching methodology may be an important factor. This study therefore evaluates critical thinking skills, using the HSRT, in pharmacy students prior to and following two academic years of TBL instruction.

Methods

TBL

The study was conducted in a pharmacy program that utilizes TBL for all didactic courses. Cohorts range in size from 69 to 108 students and teams were comprised of five to six students. Students were randomly assigned to new teams at the beginning of each semester. Instructors typically underwent training in TBL development and delivery prior to classroom instruction. All didactic courses were entirely comprised of TBL modules. Each TBL module included three phases: pre-class preparation, RAP, and application. The preparation phase involved various modalities, such as reading material and/or videos, guided by learning outcomes. The RAP involved a quiz of five to 20 multiple-choice questions taken first as individuals (iRAT), then again in teams (tRAT). iRATs contributed 5% to 15% and tRATs contributed 3% to 6% of the student's grade for each course. The RAP process concluded with a brief discussion of questions that students found unclear or confusing. Teams then proceeded to the application phase of solving challenging problems (application exercises) that typically involved either multiple-choice questions following the 4S (significant problem, same problem, specific choice, and simultaneous report) framework, where possible, and gallery walk style activities.[10] Peer evaluations were conducted part way through and at the end of each semester.

HSRT

The HSRT is a 50-item multiple-choice question test. Questions assess student aptitude in interpretation, analysis, inference, explanation, evaluation, induction, numeracy, and deduction. The overall score provides an indication of critical thinking skills, with higher scores representing stronger critical thinking skills. Overall and individual category scores on a scale of 50 to 100 are reported as superior (89 to 100), strong (81 to 88), moderate (72 to 80), weak (63 to 71), or not manifested (50 to 62). In addition to overall critical thinking scores, an overall percentile score is also provided that represents the critical thinking ability of each student in relation to a national sample of similar test-takers.

The HSRT was administered during orientation (prior to the fall semester) to students who enrolled as first-year pharmacy in fall 2015 ($n = 82$) and in fall 2016 ($n = 108$). The HSRT was then re-administered two years later, again during fall orientation (fall 2017 for the cohort that enrolled in 2015 and in fall 2018 for the cohort that enrolled in 2016).

Statistical analysis

Data were deidentified prior to statistical analysis. Graphical data and mean scores were determined using Microsoft Excel, version 16.0 (Microsoft Corp.). Comparisons of HSRT scores prior to and after TBL instruction were performed using a paired student's *t*-test. Comparison of HSRT scores for students that did and did not improve their scores was performed using Welch's *t*-test. Data were analyzed using JASP, version 0.10.2 (The JASP Team). This study was approved by the institutional review board at the University of Texas at Tyler.

Results

In this study, 163 of the initial 190 students in the cohorts that enrolled in fall 2015 and 2016 were included (Table 1). Of the initial 190 students, 27 were excluded as study participants for incomplete HSRT pre- and posttest data. Results of this study found summative improvement in the participants' overall HSRT scores from moderate to strong and an increase in percentile rank scores (Table 2). Overall, 71% of participants showed HSRT score improvement and percentile rank score from pre- to posttest (Table 3). Additionally, 99% of participants ($n = 161$) demonstrated pre- to posttest improvement in at least one domain of the HSRT. However, some participants did not show improvement. The results showed that 29% of participants demonstrated a reduction in mean HSRT score and mean percentile rank score.

Each individual HSRT domain (i.e. analysis, interpretation, inference, evaluation, explanation, induction, deduction, and numeracy) demonstrated improvement that was statistically significant (Table 3). Numeracy, deduction, and analysis domains showed the greatest improvement while evaluation, induction, and inference demonstrated the lowest percent improvement. Although the evaluation domain revealed the fewest number of students that demonstrated increased pre- to posttest scores, the outcome for all students in the evaluation domain remained statistically significant.

Table 1
Demographics of study participants.

	All students ($N = 163$) n (%)	Class of 2019 ($n = 69$) n (%)	Class of 2020 ($n = 94$) n (%)
Sex			
Female	86 (52.8)	33 (47.8)	53 (56.4)
Male	77 (47.2)	36 (52.2)	41 (43.6)
Race/ethnicity			
American Indian or Alaska Native	1 (0.6)	0 (0)	1 (1.1)
Asian	33 (20.2)	14 (20.3)	19 (20.2)
Black or African American	41 (25.2)	13 (18.8)	28 (29.8)
Latino/Hispanic	28 (17.2)	15 (21.7)	13 (13.8)
White	52 (31.9)	23 (33.3)	29 (30.9)
≥ 2	5 (3.1)	1 (1.4)	4 (4.3)
Other	3 (1.8)	3 (4.3)	0 (0)
Age, in years at study onset			
18 to 24	68 (41.7)	42 (60.9)	26 (27.7)
25 to 29	59 (36.2)	16 (23.2)	43 (45.7)
30 to 34	16 (9.8)	4 (5.8)	12 (12.8)
35 to 39	11 (6.7)	3 (4.3)	8 (8.5)
> 40	9 (5.5)	4 (5.8)	5 (5.3)
Highest degree possessed			
Two year	31 (19)	9 (13)	22 (23.4)
Four year	78 (47.9)	37 (53.6)	41 (43.6)
Professional degree	7 (4.3)	3 (4.3)	4 (4.3)
Other	47 (28.8)	20 (29)	27 (28.7)

Table 2
Mean and percentile pre- and posttest scores on the HSRT ($n = 163$).

	Pre-test (mean ± SD)	Post-test (mean ± SD)	*P* value
Overall HSRT score	76.4 ± 8.1	80.6 ± 6.9	< 0.001
Percentile rank Score	31.3 ± 25.1	44.2 ± 26.8	< 0.001

HSRT = Health Sciences Reasoning Test.

Table 3
Mean and percentile differences between pre- and posttest scores overall and in each subdomain of the HSRT ($n = 163$).

	n	HSRTscore			
		Pretest mean % (range)	Posttest mean % (Range)	Percentile change (P_i)	*P* value
Overall score					< 0.001
(+) Change[a]	115	75 (55 to 91)	81.8 (64 to 95)	9.1	
(−) Change[b]	48	79.8 (62 to 91)	77.6 (61 to 91)	−2.7	
All students	163	76.4 (55 to 91)	80.6 (61 to 95)	5.5	
Analysis					< 0.001
(+) Change[a]	99	74.3 (55 to 91)	84.5 (64 to 100)	13.7	
(−) Change[b]	64	81 (64 to 100)	77.5 (64 to 95)	−4.2	
All students	163	77 (55 to 100)	81.8 (64 to 100)	6.2	
Inference					< 0.001
(+) Change[a]	109	74.5 (56 to 91)	82.3 (66 to 97)	10.5	
(−) Change[b]	54	81 (63 to 94)	77.8 (59 to 91)	−4	
All students	163	76.6 (56 to 94)	80.9 (59 to 97)	5.6	
Interpretation					< 0.001
(+) Change[a]	86	67.2 (50 to 89)	78.9 (61 to 94)	17.4	
(−) Change[b]	77	76.2 (56 to 89)	71.7 (56 to 89)	−5.9	
All students	163	71.4 (50 to 89)	75.5 (56 to 94)	5.8	
Evaluation					
(+) Change[a]	74	65.5 (50 to 83)	73.6 (56 to 94)	12.3	0.02
(−) Change[b]	89	69.8 (56 to 94)	65.5 (56 to 83)	−6.2	
All students	163	67.6 (50 to 94)	69.2 (56 to 94)	2.4	
Explanation					< 0.001
(+) Change[a]	95	74.5 (50 to 91)	85.1 (55 to 100)	14.2	
(−) Change[b]	68	85 (64 to 95)	80.5 (59 to 95)	−5.2	
All students	163	78.9 (50 to 95)	83.2 (55 to 100)	5.5	
Induction					< 0.001
(+) Change[a]	102	77 (59 to 94)	84.7 (65 to 97)	10	
(−) Change[b]	61	83.8 (65 to 94)	81 (62 to 91)	−3.3	
All students	163	79.6 (59 to 94)	83.3 (62 to 97)	4.7	
Deduction					< 0.001
(+) Change[a]	105	69.7 (50 to 91)	79.4 (59 to 100)	13.9	
(−) Change[b]	58	79.4 (59 to 94)	75.4 (56 to 94)	−5	
All students	163	73.2 (50 to 94)	77.9 (56 to 100)	6.4	
Numeracy					< 0.001
(+) Change[a]	95	66.4 (50 to 88)	77 (58 to 96)	16	
(−) Change[b]	68	73.4 (54 to 92)	69.8 (54 to 83)	−4.9	
All students	163	69.3 (50 to 92)	74 (54 to 96)	6.8	

HSRT = Health Sciences Reasoning Test.
[a] Students that demonstrated an increase in mean score between pre- and posttest.
[b] Students that demonstrated no change or a decrease in mean score between pre- and posttest.

Discussion

This study demonstrated that pharmacy students increased their overall HSRT and percentile rank scores following two academic years of TBL instruction. The results of this current study are in contrast to work on pharmacy students (without TBL) by Cisneros[22] that demonstrated no improvement in critical thinking after one academic year of teaching. Although this comparison highlights TBL may be an effective proxy for developing critical thinking, there are method differences in the Cisneros[22] article that should be considered. For one, the previous study used the CCTST and CCTDI, whereas the current study used the HSRT. Moreover, the longitudinal span of our study was twofold (two years vs. one). Despite the noted differences, TBL does appear to be a facilitating agent for developing critical thinking in pharmacy students. The analysis also identified that those pharmacy students who did not improve their overall HSRT score had significantly higher scores on their HSRT pretest than students whose HSRT scores did improve. This suggests that TBL may be more beneficial for students who enter pharmacy school with less developed critical thinking abilities. Furthermore, students who improved their HSRT critical thinking scores performed significantly better on the posttest than students who showed no improvement, despite those students starting with higher scores on the pretest. A similar observation was made by Smith et al.,[23] where students with lower scores on the pre-test showed a greater improvement than students with higher scores. This suggests two things: (1) students with lower HSRT scores may benefit more from TBL instruction and (2) TBL is less effective for pharmacy students whose critical thinking skills are at a high level from the onset of their pharmacy education. Smith et al.[23] postulated a potential ceiling effect of the HSRT, as higher scores on the pretest aligned with higher scores on the posttest and higher performing students showed a smaller improvement than students with lower scores. Such a ceiling effect could also account for our observation that students who improved the most had lower pretest scores. Despite this potential limitation, the current study supports the use of TBL to help develop critical thinking capabilities in those students that still need growth in this skill.

The results revealed that in individual domains of the HSRT students demonstrated the greatest overall improvements in numeracy, deduction, and analysis. Analytical skills are used to consider what elements are important to a situation, to uncover assumptions, and to identify patterns.[18] TBL activities provide ample opportunities to practice analytical skills through discussion, debate, and decision making. TBL application exercises require careful consideration of multiple elements such as evaluating evidence and identifying assumptions.[24] Deductive reasoning is used to reach a logically certain conclusion, based on rules and logic.[18] In TBL, deductive reasoning most frequently occurs during RATs, where students are tested on their knowledge and understanding of preparatory material.[24] Numeracy involves all other domains of critical thinking in order to interpret the meaning of quantitative information, such as data presented in tables and graphs.[18] According to Insight Assessment, “people with strong numeracy skills can describe how quantitative information is gathered, manipulated, and represented textually, verbally, and visually in graphs, charts, tables and diagrams.”[18] TBL activities that involve interpreting quantitative information may foster the development of numeracy skills by requiring that teams discuss their understanding of the data in order to come to a consensus on the best answer. Although smaller improvements were observed in inference and induction than other domains, more students demonstrated improvement in their inference and induction scores than in other domains. Inductive reasoning involves estimating the most likely outcomes based on analogies, experiences, and observable patterns.[18] Inference is similar to induction in that it enables the prediction of possible outcomes, but whereas inductive reasoning is based on estimates, inference involves the logical consequences of decisions.[18] In TBL, application exercises often involve selecting the best answer from a selection of possible answers. This requires consideration of the likely outcomes of each option.[24] It is perhaps not surprising, therefore, that so many students demonstrated an overall improvement in induction and inference domains. It is interesting to note that average scores in inductive reasoning were higher than other domains in the pretest, possibly reflecting a ceiling effect in HSRT scores, that has been discussed in other studies (Table 3).[23] Although a smaller number of students demonstrated improvement in interpretation, those that did improve demonstrated a greater improvement than any other domain. This suggests that TBL is particularly beneficial to students with weaker interpretation skills. Interpretation involves determining meaning from information.[18] According to Insight Assessment, interpretation skills are applied to behaviors and social interactions to determine what something means.[18] TBL provides opportunities to practice interpretation though reading RAT questions, scenarios that are part of application exercises, intra-team discussion, and inter-team discussion. Further, students may be challenged on their interpretations by team members, other teams, and maybe even the facilitator, thus helping to hone interpretation skills.[24] For students where skills in interpretation were lacking, most likely due to limited exposure, TBL is an excellent forum to practice and improve. During TBL, students are frequently required to provide explanations and justify their decisions.[24] It is not surprising, therefore, that most students demonstrated improvement in explanation and that improvement was particularly observed in students who started with a lower score in this domain. Evaluation, the ability to assess the reliability of information to determine the strengths and weaknesses of arguments, is essential for pharmacists. Student scores in the evaluation domain were the lowest of all domains in both the pre- and posttest and demonstrated the smallest improvement overall. Although the improvement in scores was statistically significant, more than half of students showed no improvement in their evaluation skills. This suggests that TBL alone may not be enough to develop evaluation skills in pharmacy students.

Limitations of this research include global issues inherent to the process of critical thinking as well as study design limitations. The study participants were limited to a single pharmacy school, thereby limiting confounding variables, but also limiting extrapolation of findings to other pharmacy students at institutions with TBL pedagogy. Future research examining the relationship between the HSRT and critical thinking of pharmacy students should be extended to other institutions using TBL and to institutions not using TBL, along with appropriate controls. On a comprehensive level, it appears the HSRT was able to identify a level of benefit from TBL pedagogy for students with diminutive critical thinking abilities. A crucial question to consider is whether this benefit is in fact critical thinking acumen or the properties of confounding variables difficult to isolate. Frequency of test-taking that may improve test-taking skills, was considered a possible confounding variable for improved HSRT scores. We eliminated some of this concern with research that supports test-taking skills primarily incorporate transfer effects for short-term memory and not the deep learning and thoughtfulness needed to improve critical thinking.[25,26] We also considered findings from Hülür el al[25] that support studies using longitudinal data to measure student outcome performance can be interpreted without concern for confounding learning effects related to retest or test-taking skills. Moreover, the researcher's visibility on score calculations of the HSRT is proprietary, leaving a degree of uncertainty in the relationship between scale scores and global scores. Furthermore, there is little evidence that statistically significant changes in the HSRT scores have educational significance.[27] Future studies comparing student grade point averages or Pharmacy College Admission Test scores may help clarify this limitation.

The findings of this study support previous authors that believe critical thinking is relatively independent of content.[28] Miller[21] points out that if this reasoning is true, then “…critical thinking ability by itself will be a determinant of success in a pharmacy curriculum only to the extent that instructors' assessments require critical thinking versus recall of conten.t” Certainly, TBL supports Miller's position because the pedagogy of TBL promotes higher-order thinking to arouse critical thinking.[29] What is interesting, however, is that the TBL curriculum benefited students whose critical thinking skill was originally inferior compared to others in the cohort. It is reasonable to infer that students whose critical thinking skill was high upon entry to pharmacy school derived this skillset independent of pharmacy school or its content. Furthermore, these specific students were much less influenced by TBL on critical thinking. This suggests that Paul[28] is correct in that the skillset of critical thinking is not necessarily related to content and confirms that TBL is an effective method to develop critical thinking in students whose requisite is this particular skillset.

Conclusions

This study provided objective evidence that a TBL curriculum may improve students' overall ability to think critically. These results are encouraging and provide support that TBL can be leveraged to develop critical thinking in pharmacy students and may be especially beneficial for students who begin their pharmacy education deficient in these skills.

Disclosures

None.

Declaration of Competing Interest

None.

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