INNOVATIONS in pharmacy

Volume 7 | Number 1 Article 10

3-2-2016

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Recommended Citation

Peeters MJ, Zitko KL, Vaidya VA, et al. Critical Thinking Development in Pharmacy Education: A Meta-Analysis. *Inov Pharm.* 2016;7(1): Article 10. http://pubs.lib.umn.edu/innovations/vol7/iss1/10

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Critical Thinking Development in Pharmacy Education: A Meta-Analysis

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Author contributions: MJP conceived this systematic review. KLZ and MJP searched the literature and extracted the data. VAV and MJP analyzed the data. All authors wrote initial sections of the manuscript, and everyone provided critical review. All authors accept responsibility for this study's results and interpretation.
Conflicts of Interest: We declare no conflicts of interest or financial interests that the we or members of our immediate families have in any product or service discussed in the manuscript, including grants (pending or received), employment, gifts, stock holdings or options, honoraria, consultancies, expert testimony, patents and royalties.
Keywords: critical thinking, meta-analysis, development, assessment

Abstract
***Objective**: The investigators aimed to summarize prior studies of critical thinking development among pharmacy students, using the California Critical Thinking Skills Test (CCTST), Health Sciences Reasoning Test (HSRT), and Defining Issues Test (DIT).*
***Methods**: Independently, two investigators (KLZ, MJP) systematically searched available literature using PubMed, Google Scholar, ERIC, PsychInfo, as well as pharmacy education conference abstracts in American Journal of Pharmaceutical Education. Their search terms were 'pharmacy', and ['critical thinking', 'HSRT', 'CCTST', and 'DIT']. Studies included were those that investigated pharmacy students, used one of the tests (CCTST, HSRT, DIT), and used a longitudinal design with test administration at two or more time-points for the same subjects (i.e., development). On review, the CCTST and HSRT seem more foundational to analytical/critical thinking, while the DIT appears to measure moral/complex thinking. Summarizing used meta-analysis with Cohen's d and random-effects modelling.*
***Results**: Five studies involved thinking development with 10 separate cohorts for meta-analysis (8 cohorts for CCTST, 2 for DIT, and 0 for HSRT). At 5 institutions, 407 and 1148 students were included (CCTST and DIT, respectively). For the CCTST, the overall effect was 0.33 (0.19-0.47 95%CI) with some heterogeneity among study cohorts (I^2=52%). For the DIT, the overall effect was -0.23 (-0.83-0.37 95%CI) with considerable heterogeneity between study cohorts (I^2=95%). For the CCTST and DIT, some studies showed effect-sizes greater than 0.5. Meta-analysis of the HSRT could not be conducted (i.e., 0 studies found).*
***Implications**: While measuring different aspects of "critical thinking", the CCTST and DIT showed responsiveness to change and appear to be promising measures of cognitive development. These tests should be used in further well-designed research studies that explore strategies for improving cognitive development in pharmacy education.*

INTRODUCTION

Development of "critical thinking" has been a goal of higher education for many years.[1,2] However, evidence suggests that it is not necessarily happening everywhere.[1-3] Furthermore, an educator' intent to teach "critical thinking" does not mean their coursework actually instils "critical thinking".[4] In this manner, "critical thinking" can be a confusing concept.[5] At times, "critical thinking" seems to be unintentionally misused in place of another thinking domain such as clinical reasoning or problem-solving.[6] In an accompanying article in this issue, we provide more background regarding critical thinking, as well as its development, measurement, and implications for pharmacy education.[7] In short, recent pharmacy educational outcomes[8] introduced "habits of mind" to pharmacy education. The Dimensions of Learning model for cognition suggests that critical thinking is habit of mind, while complex problem-solving and clinical reasoning reflect complex thinking that use foundational habits of mind.[9,10]

Focused on quantifiable measurement of critical thinking, we reviewed copies of three common critical thinking tests—the California Critical Thinking Skills Test (CCTST),[11] the Health Sciences Reasoning Test (HSRT)[12] and the Defining Issues Test (DIT).[13] These tests were chosen because of their validity evidence; the CCTST and HSRT are based on work by Facione,[14] while the DIT uses Kohlberg's theory of moral development and has been widely used to measure cognitive development in higher education.[15] All three tests are self-administered, multiple-choice tests— with 34 items on the

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CCTST, 33 items on the HSRT, and 80 items on the DIT (Note: more details and a summary table are in the companion article that is also in this issue[7]). Additionally looking at a copy of each test, the CCTST and HSRT items seem like they should both assess analytical, foundational critical thinking, while the DIT appears to measure complex moral reasoning.

The objective of this investigation was to systematically summarize prior studies of critical thinking development in pharmacy education that used the CCTST, HSRT, or DIT. Summary evidence could confirm or refute the cognitive framework illustrated in the accompanying article.[7] In addition, this summary could provide evidence for instrument utility, such as the instrument's *responsiveness to change*[16,17] among pharmacy students.

METHODS

This report follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) reporting procedures.[18,19]

Literature Search

Based on the PRISMA checklist for protocols, a standardized protocol was developed and followed for study identification, inclusion and data abstraction for this investigation.[20] A systematic literature search of electronic databases included PubMed, Google Scholar, ERIC, PsychInfo, and conference abstracts within the *American Journal of Pharmaceutical Education.* Subject headings used to search the literature review were combinations of: pharmacy, critical thinking, HSRT, CCTST, and DIT. The authors also performed manual searches from the references of selected articles for further inclusion.

Study Selection and Data Abstraction

The inclusion criteria for the meta-analysis included studies that: (1) investigated pharmacy students; (2) used a longitudinal design that followed the same students over time; and (3) reported development (i.e., each student took a critical thinking test on two or more occasions). Study details were extracted using a standardized spreadsheet table that included author, journal, publication year, sample size, time between test administrations, initial mean test score with standard deviation, and final mean test score with standard deviation.

Two investigators (KLZ, MJP) independently reviewed and assessed eligibility of the studies for inclusion in this analysis. Any disagreements between investigators were resolved with discussion. The collected information included author, publication year, number of pharmacy students, and effect of 'HSRT', 'CCTST', and 'DIT'. The agreement among reviewers was very good (kappa=0.83). Figure 1 illustrates the flow of the literature search process prior to meta-analysis.

Data Synthesis and Analysis

The software MIX 2.0 Pro (BiostatXL, Mountain View, CA) was used for this meta-analysis. A random-effects model was chosen to estimate pooled mean differences.

An additional criterion for validity evidence, *responsiveness to change* is essential for evaluative assessment designs in which a change between administrations (i.e., development) is being analyzed.[16,17] Responsiveness to change differs from reliability; just because an instrument is reliable does not mean it is also responsive to change. Responsiveness to change requires finding a difference between scores from multiple instrument administrations in the same participant. However, indication of responsiveness to change using only statistical significance can be statistical artefact and can lack practical significance. Looking beyond statistical significance to practical significance, effect-sizes can provide evidence of a practical magnitude.[21] As is common in social sciences meta-analyses, Cohen's d estimates of effect size were used as evidence of practical significance[21] and to indicate the standardized difference between those means. In this study, we also used the standard error of measurement as a distribution-based index of practical significance to compare with study effect-sizes.[21] Assuming a reliability of 0.75, we calculated an SEM of 0.5 x standard deviation, which is equal to a Cohen's d of 0.5 [medium effect-size], as our threshold for tests to suggest practical significance.

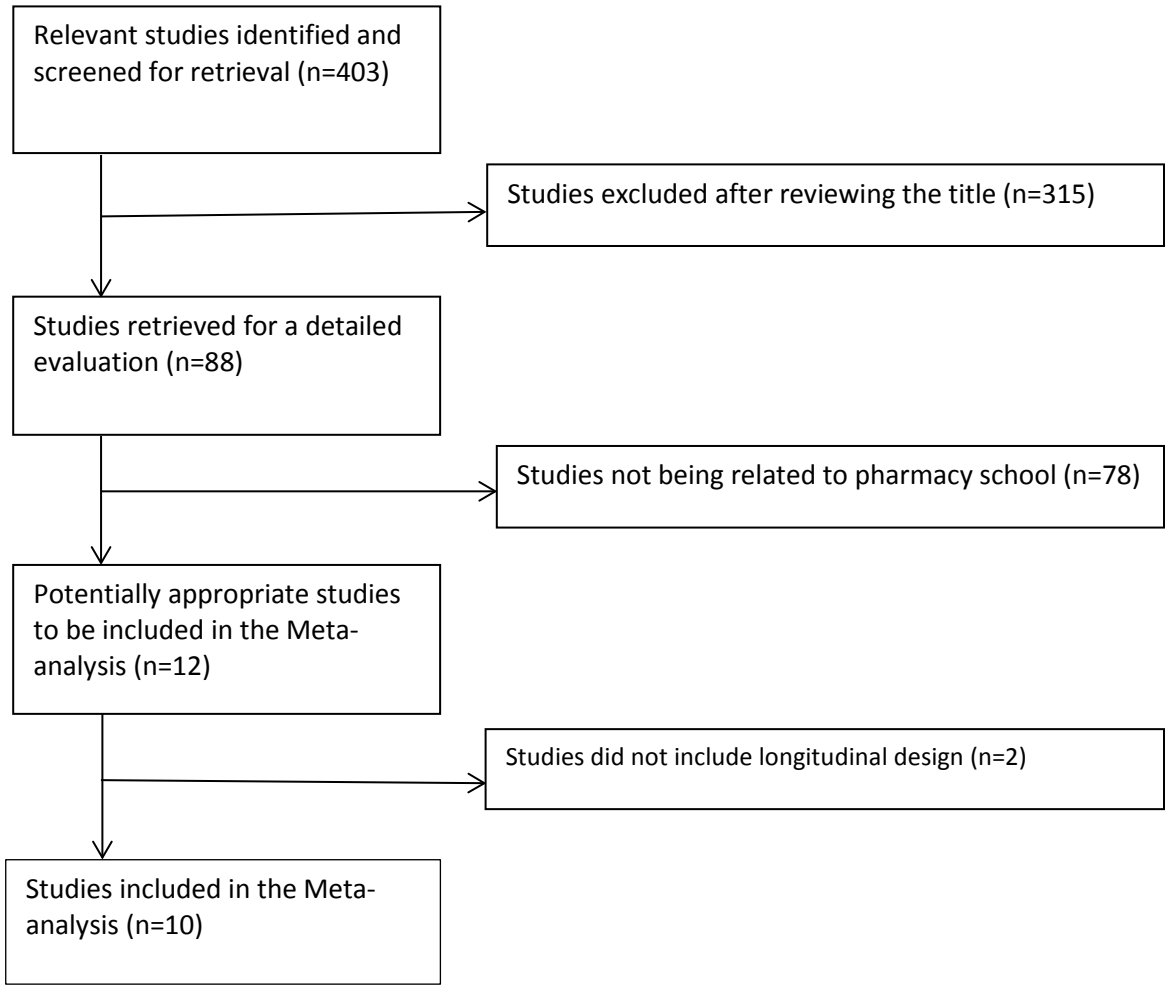
Presence of heterogeneity among studies was derived with the I^2 index. As a rough guide for I^2 interpretation for heterogeneity, the *Cochrane Handbook for Systematic Reviews of Interventions* provides 0%-40% might not be important, 30%-60% may be moderate, 50%-90% may be substantial, 75%-100% may be considerable (though special attention is noted in the *Handbook* that interpretation of I^2 can be misleading).[22]

RESULTS

Overall, 1,555 pharmacy students had been investigated within 10 cohorts for this meta-analysis, including 407 students for the CCTST and 1148 students for the DIT. Eight cohorts used the CCTST, while only two used the DIT. These cohorts were from five institutions. No studies were found for development in critical thinking among pharmacy students using the HSRT.

A total of eight comparisons were found between the CCTST reports in pharmacy education. As seen in Figure 2, the pooled effect size for 407 students was found to be statistically significant at 0.28 Cohen's d [95% confidence interval 0.07-0.49; p=0.04]. These studies showed moderately heterogeneous results, with an I^2 =52%. As seen in figure 3, two studies of cognitive development in pharmacy education used the DIT. The pooled effect size for 1148 students was

Figure 1. The PRISMA flow diagram[18,19] of inclusion of articles through stages of this meta-analysis.



found to be statistically significant at -0.23 Cohen's d [95% confidence interval -0.82-0.37; p<0.01]. These study results had considerable heterogeneity with an I^2 =95%.

For responsiveness to change, both the CCTST and DIT showed a Cohen's d effect-size greater than 0.5 or less than -0.5 for some individual studies. This can be seen in both figures 2 and 3. Notably though, the pooled effect size was not greater than 0.5 for either test; *all* studies did not have medium effect-sizes for either the CCTST or DIT (however as seen in Figure 3, the DIT had a report of a 0.5 decrease, instead of improvement, within one cohort of pharmacy learners).

DISCUSSION

The CCTST and DIT results were dissimilar, suggesting that different types of cognition may be measured with each test. However, both the CCTST and the DIT have been described as measures of critical thinking. The CCTST, which is based on the American Philosophical Association's definition of critical thinking,[23] appears to assess analytical, foundational critical thinking. Meanwhile, the DIT, based on Kohlberg's theory of moral development,[24] assesses a more complex moral reasoning.[15] In short, not all "good thinking" should be termed "critical thinking." Critical thinking and complex thinking (such as problem-solving and moral reasoning) are different though related; complex thinking may rely upon foundational critical thinking as a habit of mind.[7] Others have also noted this confusion in using the term "critical thinking".[5,6] For example, in Krathwohl's revision of Bloom's Taxonomy the term "critical thinking" was specifically avoided because of the variation noted among educators when using this term.[25]

With some medium effect-sizes (Cohen's d >0.5 or <-0.5) for both the CCTST and DIT, Figures 2 and 3 illustrate that both the CCTST and the DIT showed some *responsiveness to change*. This is an essential need for using any test to assess change (i.e., development over time) and is a promising finding for the CCTST and DIT. The heterogeneity seen in the results of both the CCTST and DIT demonstrate that neither test will always find growth all of the time. Colleges/schools of pharmacy need to assess their students' growth, within their specific educational contexts. Because of a lack of evidence, we remain unsure about the HSRT's responsiveness to change; this should be interpreted as an example of absence of evidence not equalling evidence of absence. For the DIT, it is interesting that little evidence of its developmental effectiveness exists in pharmacy education, and no reports with positive development as yet. It is helpful to know that our findings in this meta-analysis did confirm a broader systematic review that had also included other health professions;[26] students learning in health profession programs other than pharmacy demonstrated positive development—but why not pharmacy?

Notably, the DIT is also a quantitative assessment of professionalism,[27,28] while an improvement of scores with repeat administrations has signified development by others.[3,29] The DIT has been recommended for assessing development by leaders in pharmacy education.[28,30,31] Thus, the DIT may also be used to measure development of professionalism (i.e., Standard 4.4 from Standards 2016[32]). It is encouraging that a recent report in pharmacy education has shown effectiveness in this area.[33,34]

Categorically, meta-analysis can be limited by publication bias. In addition, while investigators attempt to search completely, they may miss a report. In this study, we had searched multiple databases of published articles *and* delved into grey literature, such as the American Association of Colleges of Pharmacy Annual Meeting abstracts published in *the American Journal of Pharmaceutical Education*, but not searched other potential grey literature, such as doctoral dissertations, that were not in abstracts or subsequently published. The small number of relevant studies limits these findings. While the present study serves to summarize prior findings in the literature, we cannot rule out that other unpublished results could influence these findings. We encourage other pharmacy programs to share their findings to help make a similar, future meta-analyses more robust.

Heterogeneity was found among the limited number of studies. As a result, the point-estimates for pooled effect-size with each test should be taken as "not zero"; the magnitude should be interpreted based upon the moderate-to-considerable heterogeneity identified. While these tests all assessed pharmacy students, this heterogeneity highlights the significant role of each institution's 'educational context';[35] different schools are in different locations with interactions between different educators and diverse students, and so every learner will develop differently based on their varied experiences. Due to the small number of studies, we did not undertake any subgroup analyses to investigate the heterogeneity further. Additionally, cluster bias may have influenced our heterogeneity estimates.[36]

CONCLUSION

The CCTST and DIT appear to be promising measures of cognitive development, though they measure different aspects of it. From a psychometric perspective, both tests showed responsiveness to change in at least some studies. These tests warrant use in future investigations of methods to improve cognitive development in pharmacy education. For the DIT, little evidence has been reported in pharmacy education, and none with positive development as yet. Currently, there is no evidence in pharmacy education for

Figure 2. Forest plot summarizing California Critical Thinking Skills Testreports in pharmacy education

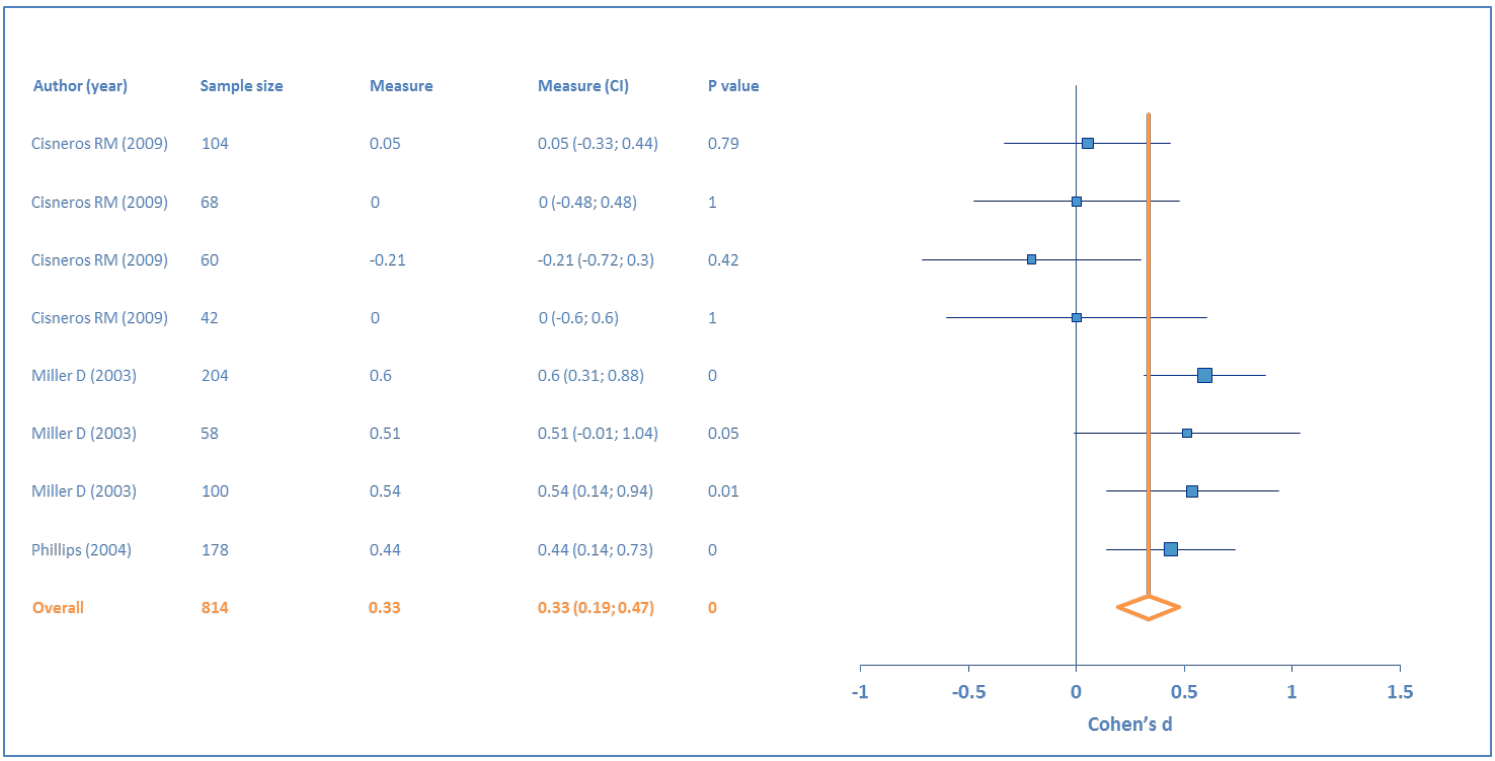
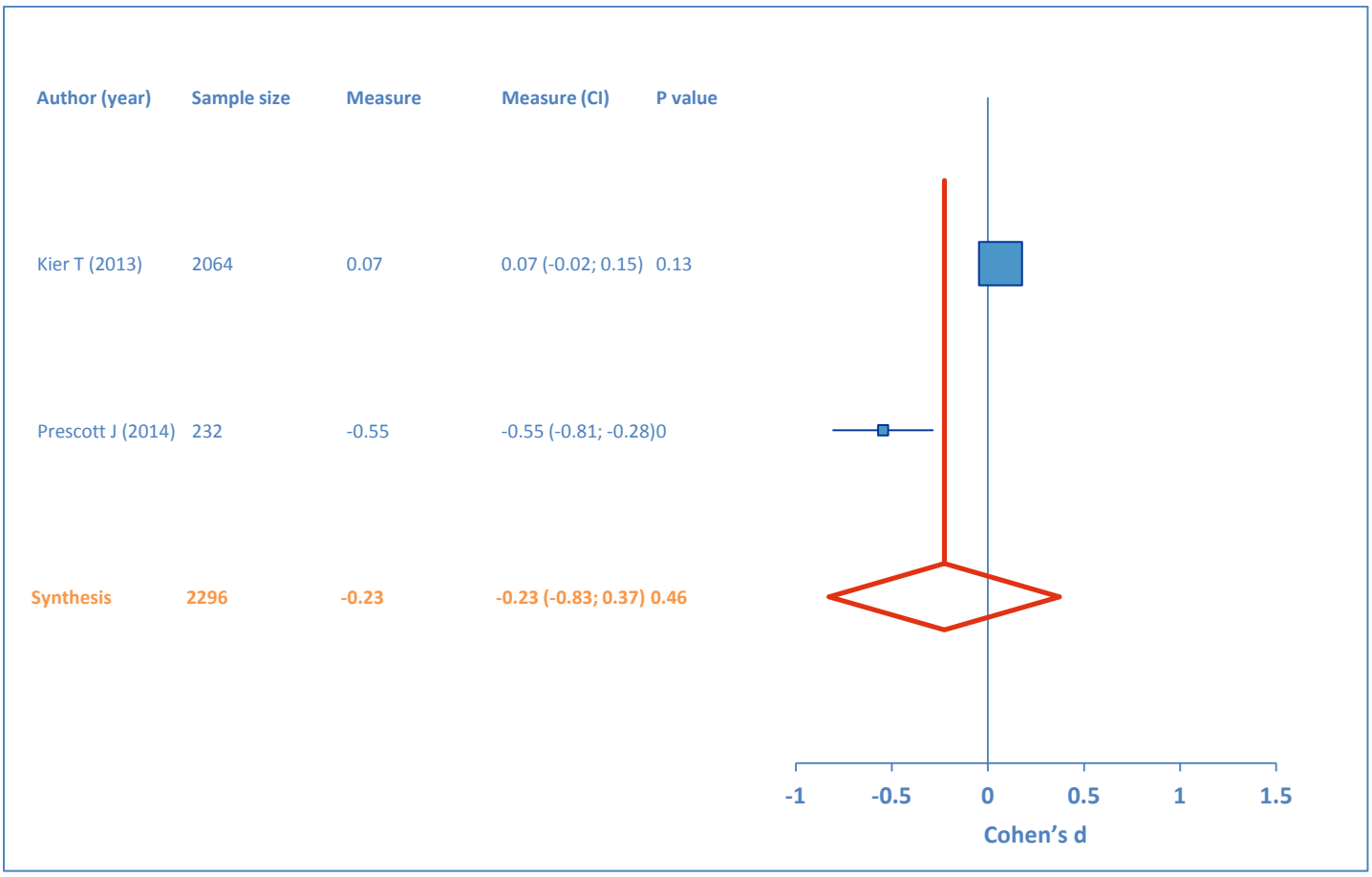


Figure 3. Forest plot summarizing Defining Issues Test reports in pharmacy education



using the HSRT to assess critical thinking development. Given the small number of studies identified, we encourage other pharmacy education investigators to disseminate their findings using the CCTST, HSRT, and/or DIT. Incorporating further results into a future meta-analysis may advance our understanding further and allow a systematic review to further explore characteristics that could facilitate or impede cognitive development among pharmacy learners.

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