BRIEF

Concept Mapping Activity to Enhance Pharmacy Student Metacognition and Comprehension of Fundamental Disease State Knowledge

Brandon D. Powell, PharmD,[a] Madison S. Oxley, PharmD,[a] Kevin Chen, PharmD,[a] Heidi Anksorus, PharmD,[b] Robert Hubal, PhD,[b] Adam Persky, PhD,[b,c] Suzanne Harris, PharmD[b]

[a] University of North Carolina Medical Center, Chapel Hill, North Carolina
[b] University of North Carolina at Chapel Hill, Chapel Hill, North Carolina
[c] Associate Editor, *American Journal of Pharmaceutical Education*, Arlington, Virginia

Corresponding Author: Brandon D. Powell, University of North Carolina Medical Center, 5760 Farrington Rd, Chapel Hill, NC. Tel: 205-612-3945. Email: Brandon.powell@unchealth.unc.edu

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Objective. To examine the impact of pre-class concept mapping on students' ability to self-assess their degree of foundational disease state knowledge (metacognition), as well as pre-class quiz performance.
Methods. Second-year pharmacy students in a problem-based learning course were responsible for self-directed learning of foundational knowledge for 14 disease states. After completing independent pre-class reading, students either (1) created group concept maps for which feedback was provided; (2) created group concept maps with no formal feedback; or (3) had no formal group activity. The next day, prior to the formal in class discussion, students completed a quiz covering foundational knowledge and predicted the number of questions they would answer correctly before completing the quiz. Quiz performance was compared between the three conditions, and bias and absolute bias were calculated to evaluate metacognitive skills.
Results. There was no difference in metacognition among the conditions, as reflected by inaccuracy between predicted and actual quiz scores. However, when students engaged in concept mapping, their quiz performance was significantly higher than the business-as-usual control.
Conclusion. Concept mapping did not improve metacognitive skills but did have small effects on quiz performance. More research is needed to tease apart the roles of concept mapping, group activity, and feedback in altering quiz performance and metacognitive skills.
Keywords: metacognition, concept mapping, pharmacy education, active learning

INTRODUCTION

In the current age of rapid advancement of medical practice, pharmacy students must acquire skills to become critical thinkers and self-directed, lifelong learners. An important component in the learning development of pharmacy students is metacognition. Metacognition is "knowledge and cognition about cognitive phenomena as well as monitoring of one's own memory, comprehension, and cognitive enterprises".[1] More simply, metacognition is "thinking about thinking".[1] A fundamental skill of metacognition is accurate self-assessment; utilization of this skill has clearly been associated with classroom performance. Two studies found that high-performing students demonstrate more accurate self-assessment of their abilities compared to low-performing students, and are better able to identify incorrect items on an exam.[2,3] A study evaluating pharmacy student confidence level and willingness to seek help with drug-information questions found students were overconfident and less willing to ask for help with unfamiliar topics.[4]

Pharmacy graduates should be able to examine and reflect on their personal knowledge, skills, and abilities; therefore, it is imperative pharmacy curricula implement learning strategies utilizing metacognition. One increasingly prevalent strategy is the use of concept mapping. Concept maps are graphical representations depicting concepts related to one another, and are used as an educational technique to improve understanding of course material, integrate didactic and experiential knowledge, and encourage higher order learning.[5] Concept mapping activities have demonstrated improved metacognitive accuracy and increased critical thinking skills in assessments evaluating nurses and pediatric medical residents.[6,7,8] Concept mapping is currently being used in pharmacy curriculums to teach disease states and the Pharmacists' Patient Care Process, as well as for assessment purposes.[9,10,11]

Performing concept mapping may improve metacognition by cue-utilization. Cue utilization refers to using "cues" that are predictive of future learning which has demonstrated enhanced judgement of learning.[12] Using concept maps as a study tool requires judgement of learning and reflection (i.e. a cue), both of which may improve student self-assessment – an important element of metacognition. The study aim was to evaluate if concept mapping and providing feedback on concept map performance would enhance students' ability to self-assess their mastery of therapeutic topics.

METHODS

The study included second-year pharmacy students in a case-based learning pharmacotherapy course, the second of five standalone courses in the pharmacotherapy series that also serves as a transition to problem-based learning. The course ran parallel to a patient care lab course where students met weekly in assigned small groups of 8-9 students, and the lab course activities supplemented the case-based learning pharmacotherapy course lectures. Student lab groups were assigned at random to include a distribution of high and low performing students. Lab groups remained the same throughout the semester. In the pharmacotherapy course, a new disease state was introduced at the start of each week through independent pre-class readings. Readings were assigned by the lecturing content expert and consisted of the respective chapter of *Pharmacotherapy: A Pathophysiologic Approach*,[13] primary literature, and/or clinical practice guidelines. Following the pre-class reading, students met in their assigned lab groups led by a resident teaching assistant. The day following lab, students attended the pharmacotherapy course lecture. The students completed a pre-class quiz covering the foundational disease state knowledge prior to partaking in case-based learning led by the content expert. The study included fourteen disease states and pre-class quizzes.

The fourteen disease states were pseudorandomized into three conditions based upon the predetermined course schedule and content expert lecturers. One of three conditions was assigned weekly to the course topics to be carried out in the patient care lab course, consisting of: (Condition 1) creating group concept maps for which feedback was provided via review of an expert key; (Condition 2) creating group concept maps with no formal feedback; or (Condition 3) no formal in-class activity (business-as-usual control). Each disease state was assigned to a condition as follows: Condition 1: anemia of CKD, rheumatoid arthritis, heart failure, asthma; Condition 2: liver disease, hyperlipidemia, urinary tract infection; Condition 3: fluid and electrolytes, bone mineral disease of CKD, GI disease, osteoarthritis, osteoporosis, seizures, upper respiratory infection. The study consisted of a within subject design with students serving as their own control, as all students in their assigned lab group covered the same disease state with a specific condition each week.

During weeks in Conditions 1 or 2, students were given 45 minutes during lab to create a concept map with their assigned small group. Students were given guidance to include 50-70 terms within their concept maps in the following six domains: pathophysiology/etiology, signs/symptoms, diagnosis, goals of care, treatments, and monitoring/follow up. Using their notes from pre-class readings, groups had the option of developing a concept map on a whiteboard or electronically using a word mapping software.

After concept mapping disease states assigned to Condition 1, students received feedback via review of a content expert approved key. The students were given 5 minutes to review the concept map key after which they participated in 5 minutes of individual reflection. The reflection was guided by pre-determined questions assessing how well the students mapped the specified domains to the level of the key. The individual reflection was followed by group discussion/reflection for 10 minutes. For disease states assigned to Condition 2, the small groups developed a concept map but were not given feedback via review of a content expert's key nor time for self- and group-reflection. Teaching assistants were instructed to remain hands-off during the concept mapping activities and facilitated the reflections by asking pre-determined questions.

Prior to the beginning of the large group lecture, the day following patient care lab students completed a multiple-choice pre-class quiz regardless of which Condition was assigned. The quiz assessed the foundational disease state knowledge expected to be gleaned from pre-class readings, and further reinforced through concept mapping for Conditions 1 and 2 or reinforced using the students' preferred study methods for Condition 3.

Prior to completing the quiz, students were required to predict the number of quiz questions they would answer correctly in order to assess metacognition. Two measures of metacognition were used.[14] The first was bias – a measure of under- or over-confidence, calculated by the difference between the predicted score and the actual score (predicted – actual). Negative scores indicated under-confidence (actual>predicted) and positive scores indicated over-confidence (predicted>actual). The second measure was absolute bias - a measure of predicted quiz performance accuracy, calculated as the absolute value of bias.

Conditions were compared using a paired t-test. For multiple comparisons, a Bonferroni adjustment was performed for three comparisons. To elucidate time effects, a general linear model was applied using repeated measures. Significance was set at $p<.05$ ($p<.017$ for multiple comparisons). Effect size was calculated, when appropriate, using

Cohen's D with d<0.5 as a small effect, 0.5≤d≤0.8 as a medium effect and d>0.8 as a large effect. This study was approved by the University of North Carolina at Chapel Hill Institutional Review Board.

RESULTS

Of the 143 second-year pharmacy students, seven did not consent to have their data included and were excluded from analysis. Another 19 were excluded for incomplete data as defined as missing >20% of data (eg, did not predict grades on multiple quizzes). Of the 136 students included, 12 students reported utilizing concept mapping as an independent study method for at least one of the seven disease states in Condition 3 (business-as-usual).

Because of the difference in the number of topics within each condition (four topics in Condition 1, three topics in Condition 2, and seven topics in Condition 3), Conditions 1 and 2 were initially combined (seven topics) and compared to Condition 3 (seven topics), thus comparing group concept mapping to the business-as-usual control to create two equal comparators. When students engaged in group concept mapping, their quiz performance was significantly higher with a small to moderate effect compared to the business-as-usual control (94 ± 5% vs 91 ± 6%, d=0.57, p<.001). However, there was no difference in the predicted scores on quizzes (83 ± 10% vs 82 ± 10%, d=0.08, p=.06). We then examined the under- and over-confidence of students within each condition. When students engaged in group concept mapping, they showed a small but significantly higher degree of under-confidence compared to the business-as-usual control (-11 ± 10% vs -9 ± 11%, d=0.18, p=.002). However, there was no difference in their accuracy (15 ± 9% vs 14 ± 8%, d=0.10, p=0.1).

This analysis was repeated by examining the three conditions: group concept mapping with feedback (four topics); group concept mapping without any feedback (three topics); and business-as-usual control (seven topics). The greatest difference in quiz performance was observed with group concept mapping without feedback (95%, d=.36 vs feedback; d=.66 vs control), followed by group concept mapping with feedback (93%, d=.36 vs control), and lastly the business-as-usual (91%). There were no differences between Conditions for students' predictive scores. For topics in which students completed the group concept mapping and received no feedback, they showed more under-confidence (-12%) compared to the control condition (-9%)(d=.26). In addition, the topics for which students received no feedback after group concept mapping resulted in less accuracy of prediction (14%) compared to control condition (11%)(d=.31) (Table 1).

Because metacognitive judgments are impacted by practice, potential time effects were examined but yielded no significant linear trend for quiz scores (Figure 1) or prediction of scores over time. However, the second quiz demonstrated significantly lower predictions than any other quiz (Figure 1). There was no linear trend in bias, a measure of over- or under-confidence, but students started at and remained under-confident throughout (Figure 2A). When examining accuracy, there was a near significant linear trend (p=0.06) showing improved accuracy over time. (Figure 2B)

DISCUSSION

These results demonstrated improved quiz performance when students participated in concept mapping, but concept mapping did not impact metacognition. Despite an increase in actual quiz score in Conditions 1 and 2, students consistently predicted the same score across all three Conditions. The greater discrepancy between actual and predicted quiz score was evident by greater bias and absolute bias when evaluating both Conditions 1 and 2 compared to Condition 3, though only Condition 2 met statistical significance. However, it is interesting to consider if poorer accuracy could actually reflect improved metacognition. Underpredicting quiz scores to a greater degree in the concept mapping Conditions could indicate that students have more awareness of the material they are unfamiliar with, and self-awareness is an important component of metacognition.

Although quiz performance was significantly higher when students completed concept mapping compared to the business-as-usual control, it is important to consider if this difference is significant enough for students to engage in concept mapping independently. A score of 94% versus 91% on a 10-point quiz may not represent a meaningful difference to students. Perhaps this is demonstrated by only 12 students reporting use of concept mapping for at least one disease state assigned to Condition 3. The low rate of independent concept mapping in Condition 3 could also be attributed to this being an unfamiliar study technique, and students feeling more comfortable using their previous study methods. It is also possible students found other study techniques to be more efficient, or that students did not prioritize concept mapping for a pre-class assignment when managing their other coursework.

Future study directions should include the impact of concept mapping on comprehensive exam performance, long-term retention, integration of information, and self-regulated learning. Should concept mapping be utilized more in the future, a challenge posed to educators is ensuring standardized and objective evaluation of students' maps.[15] Kolar et al. developed a grading tool that our authors utilized, though it is non-specific and subject to different interpretations by different evaluators.[10]

Though our study ultimately showed positive results with concept mapping, it does have limitations to consider. Disease states were not distributed evenly among the three conditions which could lead to potential sampling bias and variations in topic difficulty. The topics were unable to be counterbalanced based on the predetermined course schedules and alignment with patient care lab activities, which is a limitation of a study designed around a real world, preexisting pharmacy course. Quizzes were developed by the respective content expert for each disease state, further contributing to variation in difficulty. Additionally, quizzes varied in the number of questions, though all quizzes were normalized to 10-points. Finally, students made metacognitive judgements for overall quiz performance (a global judgement), therefore results may differ if students made topic-level judgements (eg, pharmacology, therapeutics, epidemiology, etc.) within the quiz.

This study does have several strengths. Students were their own control in this within-subject design. The within-subject study design improves the ability to assess individual students' progress throughout the different Conditions. It would be unethical to randomize students to different learning conditions in a core pharmacotherapy class where the intent is for all students to have similar learning experiences. Data analysis was adjusted for time to account for students becoming better at predicting quiz scores with more practice as the semester progressed. Additionally, the small lab groups that students worked in to develop their concept maps were assigned at random, promoting an even distribution of historically high and low performing students.

CONCLUSIONS

While concept mapping activities did improve student quiz performance, they did not affect their metacognition measured by bias and absolute bias. Future studies are warranted to assess utility of concept mapping in pharmacy education and students' perceived barriers.

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Table 1. Summary of quiz performance, predictive performance and metacognitive measures for the 3 study conditions (n=117)

	Group Concept Mapping with Feedback	**Group Concept Mapping without Feedback**	**Business-as-Usual Control**
Performance (out of 100 points)	93 (5) [a]	95 (6) [a b]	91 (6)
Prediction (out of 100 points)	83 (11)	83 (11)	82 (11)
Bias	-11 (11)	-12 (12) [a]	-9 (11)
Absolute Bias	12 (9)	14 (10) [a]	11 (9)

Results reported as "Mean (SD)"
[a] significantly different than control (p<.017 threshold)
[b] significantly different than group concept mapping with feedback (p<.017 threshold)

Figure 1. Time course of quiz scores and predicted scores. Group concept mapping with feedback is gray, group concept mapping without feedback is white, and business-as-usual-controls are black.

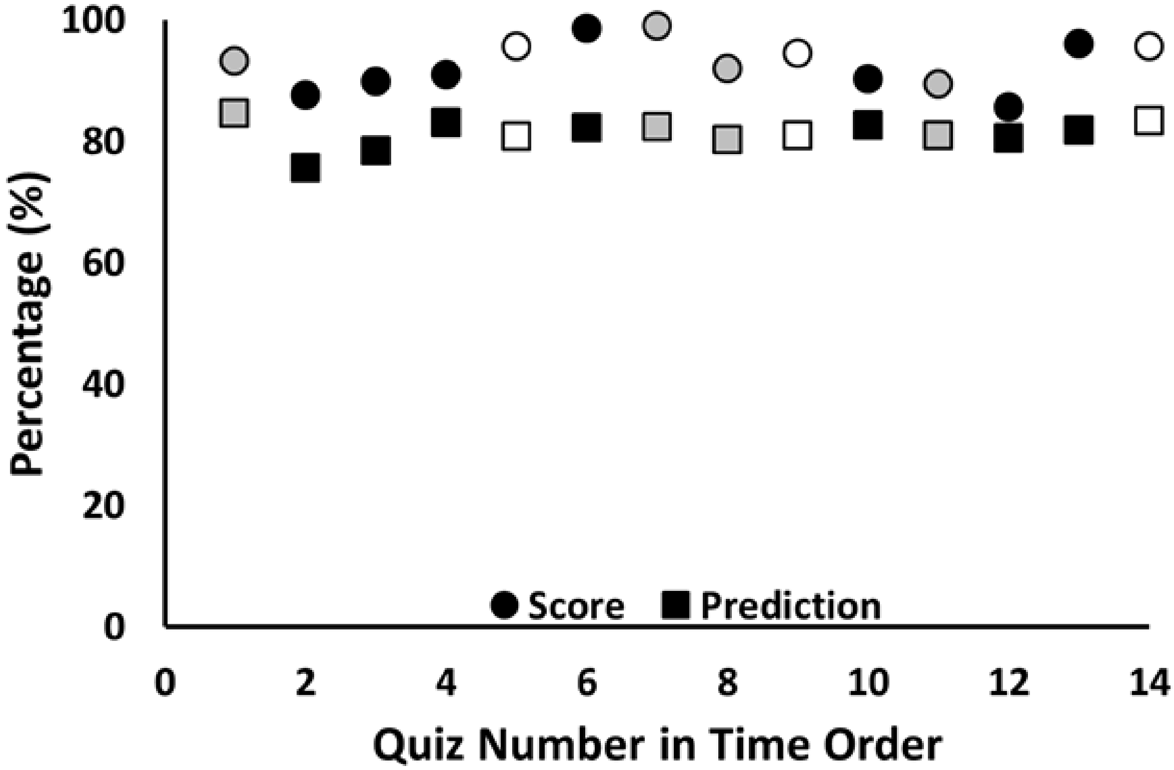

Figure 2. Time course for metacognitive changes in under-confidence (A) and accuracy (B). Group concept mapping with feedback is gray, group concept mapping without feedback is white, and business-as-usual-controls are black.