The Peripheral Brain: A Tool To Foster Higher-Order Thinking in Abilities-Based Courses

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Student-centered educational strategies that stress problem-solving appear to be more effective than traditional, instructor-based methods in preparing students to practice pharmaceutical care. To address this issue, an abilities-based approach was developed in which students compile a reference handbook, or "peripheral brain" (PB), to increase opportunities to practice higher order thinking skills in pharmacotherapy courses. Criteria for the compilation and evaluation of the PB were created collaboratively by students and instructors and were then used to assess and provide feedback to students. In order to determine the impact of PBs on exam content, a retrospective analysis was performed to evaluate the types of questions asked in pharmacotherapy midterm and final exams prior to and after implementation of the PB system. To evaluate the effect of the peripheral brain on student performance, pharmacotherapy exam questions were classified according to Bloom's Taxonomy of Thinking and students' percentage scores on exams of varying taxonomic content were evaluated. Exam questions more frequently tested higher order thinking skills post-PB compared to pre-PB (94 vs 44 percent, respectively). Although post-PB exams were more challenging, post-PB and pre-PB mean exam scores did not differ (75 and 73 percent, respectively, P = ns). Analysis of post-PB exams revealed a significant inverse correlation between student exam performance and number of higher order taxonomic questions (r = -0.78, P < 0.05). Continuous assessment and feedback significantly improved the quality of the students' PBs (P < 0.001), suggesting that higher order thinking skills also improved. It is concluded that the PB serves as an effective learning tool for improving students' higher order thinking skills in pharmacotherapy courses. However, while the PB serves to facilitate the practice of problem-solving, by itself it is not sufficient to develop critical thinking skills.

BACKGROUND
Contemporary pharmacy educators have emphasized the importance of teaching students to become responsible, active learners(1). Indeed, evidence suggests that student-centered approaches stressing problem-solving appear to be more effective than traditional, instructor-based methods in helping students develop the skills and attitudes necessary to practice pharmaceutical care(2). Most experts agree that higher order cognitive abilities are a prerequisite for effective clinical problem-solving(3-5). This requires that professional curricula not only emphasize the acquisition and understanding of factual information, but also provide continuous opportunities to use this information to practice higher order thinking. The tremendous volume of facts that a student must "know" when learning to apply pharmacotherapeutic principles to patient-specific problems can pose a barrier to developing problem-solving skills(6). That is, because students are often required to memorize large amounts of information, they have little opportunity and time to integrate and relate this information to professional practice.

To better promote the practice of abilities necessary to render pharmaceutical care, in 1995 we began to revise our teaching methods. We continued to provide "content" or knowledge questions that students must commit to memory but we began to replace some lecturing with instruction based upon case studies and to organize small groups for case study discussion.

What brought coherence to the pedagogy was an ability-outcomes educational model which emphasizes what pharmacy professionals "do," not just what they "know." In the ability-outcomes model, students, to successfully achieve an ability, must effectively apply knowledge; employ skills; and exhibit appropriate values, attitudes, and habits. Thus in these abilities-based courses, there was a focus on the application of knowledge (for example, the understanding of pharmacology), the practice of skills (for example, organization, prioritization, justification), and the demonstration of attitudes (for example, responsibility, assertiveness and motivation). We have described various means of delivering abilities-based education elsewhere(7). In general, this approach involves: (i) describing clearly what the student will be expected to do (the "ability outcome"); (ii) creating multiple assignments and opportunities to practice the outcome ("practice"); (iii) providing explicit indicators of successful performance ("performance criteria"); and (iv) giving specific suggestions to improve performance ("feedback") (Figure 1)(8).

However, during initial efforts to focus on the performance of abilities, we realized that students' primary emphases still were being placed on acquiring and cataloging information rather than on the ultimate use of their knowledge. Although it is crucial that students develop a baseline knowledge base, it is also vital to assist them in using the information(9,10). Thus, we have assigned all students the task of creating a self-compiled reference handbook, or "peripheral brain" (PB), for use in all required pharmacotherapy courses since Fall of 1994. The purpose for the implementation of the PB was to provide more opportunities for our students to practice and be assessed on
their higher-order thinking skills. Hence, this project reflects efforts over the past three years to alter the students’ learning paradigm from one of “acquiring and memorizing” information to one of “thinking about and using” knowledge and skills to practice pharmaceutical care(1).

PROCESS

The peripheral brain was implemented in three stages:

- **Stage I: Development of the peripheral brain and performance criteria**
- **Stage II: Application of performance criteria**
- **Stage III: Evaluation of the impact of peripheral brains on student performance**

**Stage I: Development of the Peripheral Brain and Performance Criteria**

In Fall, 1994, as part of a required fifth-year PharmD therapeutics course (n = 45), each student created a self-compiled pocket handbook of clinically useful information, hereafter referred to as the “peripheral brain” (PB). Students were required to find and comprehend primary, secondary, and tertiary sources of information relating to pharmacotherapy and then to analyze the information and assess its relevance to therapeutic principles and clinical problems. Students were oriented to the peripheral brain through a representative example. The following instructions were given:

*It is intended that the handbook function as a useful and handy reference for future use during your clinical rotations. Include information that will help you in your day-to-day clinical activities (e.g. algorithms for treating hyponatremia, ACLS guidelines, calculation for osmolality and anion gap, equations for estimating creatinine clearance.)*

Throughout the semester, students voiced the need for more explicit directions to compile their PBs. In response to this concern, we decided to help students to develop explicit criteria for construction of a “good” PB. Performance criteria are indicators of successful performance; they describe what the student must do to perform successfully the assignment, and they provide guidelines by which quality of performance is measured(8). However, we recognized that when presented with criteria, students often do not understand them. They may not fully understand the terminology (for instance, they may not know all that is involved in “synthesizing information” or “recommending drug therapy”) or they may be unable to accurately apply the criteria to specific performances because they have not had any opportunity to compare their assessments with others’.

Thus, in the last three weeks of the semester we decided to have the students work empirically to create their own performance criteria. We asked them, “what is needed to complete a useful PB?”

The process began by showing students five different examples of PBs compiled by peers in the fifth-year Therapeutics course. They were asked to identify the “strengths” and “weaknesses” of each PB and then analyze these traits to identify the qualities of a “good” PB. The students then used this list to develop a set of performance criteria for PB evaluation which was clearly understood since the criteria were student-generated. The course instructors modified the student-generated performance criteria slightly to enhance clarity and consistency. The resulting four categories were: retrieving, organizing, processing, and relating information (see Appendix A). Once finalized, the performance criteria were used prospectively during the Fall semester of 1995 to guide development of the PB in our fourth-year Therapeutics I course.

**Stage II: Application of Performance Criteria**

In the Fall 1995 fourth-year therapeutics course (n = 132), the performance criteria were presented on the first day of class. Then, three times during the semester, the PBs were collected and assessed, and feedback was provided by the instructor and peers. Students continued to compile the PBs throughout the semester, making revisions based upon the feedback provided.

**Stage III: Evaluation of the Impact of Peripheral Brains on Student Performance**

All students from both the 1994 fifth-year and 1995 fourth-year classes had been allowed to use the PB as a reference during pharmacotherapy exams so that instructors could shift exam emphasis to questions requiring analysis, synthesis, and evaluation skills. Recall and comprehension were tested less frequently because students had access to this information in their PBs, if they were developed correctly.

The classification of exam questions was based upon Bloom, who states that thinking skills can be arranged in a hierarchical order, proceeding from the initial acquisition of knowledge through the increasingly complex steps of comprehension, application, analysis, synthesis and evaluation(11) (Appendix B). Acquisition of knowledge requires recall or memorization of information; comprehension requires not only recall, but understanding as well; application is the use of information and facts within new contexts. The last three levels, analysis, synthesis, and evaluation, are often termed “higher order” thinking skills. Analysis enables one to take something apart, understand its structure, and see how the pieces fit together; synthesis is the skill to put things together, to draw ideas from numerous sources and derive a new thought; evaluation is the determination of value, correctness, or merit.

**Part I:** In order to verify the impact of PBs on exam content, a retrospective analysis was performed to evaluate the types of questions asked in pharmacotherapeutic midterm and final exams administered prior to (pre-PB, 1993) and after the implementation of the PB system (post-PB, 1994). Two faculty members (one pharmacy and one non-pharmacy
faculty member) classified the exam questions according to Bloom’s Taxonomy of Thinking Skills (Appendix B) as follows:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Taxonomic Category</th>
<th>Thinking Skill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Bloom’s I, II</td>
<td>Recall, Comprehension</td>
</tr>
<tr>
<td>Level 2</td>
<td>Bloom’s III</td>
<td>Application</td>
</tr>
<tr>
<td>Level 3</td>
<td>Bloom’s IV, V, VI</td>
<td>Analysis, Synthesis, Evaluation</td>
</tr>
</tbody>
</table>

The mean student exam scores were also compared pre-PB and post-PB.

**Part II: Pharmacotherapy courses in both fourth and fifth-year therapeutics courses were again inventoried using Bloom’s Taxonomy to identify any differences in student performance between the fifth-year class who utilized PBs without criteria/feedback and the fourth-year class who utilized PBs with criteria/feedback. Students’ mean exam scores were compared to determine if there was an association between student performance and exam taxonomy.

**Student Perception of PB**

An open-ended questionnaire was administered only to fourth-year therapeutics students at the end of their Fall 1995 semester. The students were asked questions regarding the process and time necessary to compile the PB, i.e., the extent of usage of handouts and physiology, pathophysiology, pharmacology and therapeutics texts and time required to construct the PB. Use of the PB was assessed by inquiring how valuable the student’s PB was during homework cases and exams and for what reasons it was used, i.e., looking up dosage regimens, reviewing pharmacologic and pathophysiologic mechanisms; selecting and recommending therapy; determining monitoring parameters. Finally, students expressed their opinions about the pros and cons of the PB.

**Statistical Analysis**

The PB assessments conducted three times during the fourth-year therapeutics course were compared statistically using the Kruskal-Wallis One Way Analysis of Variance (SigmaStat, version 2.0). The Mann-Whitney Rank Sum Test evaluated the difference between the fourth and fifth-year final PB assessments. The student’s t-test was used to analyze the difference between mean student exam scores pre-PB and post-PB. Students’ mean exam scores were correlated with exam taxonomy utilizing the Pearson Product Moment Correlation. The a priori level of significance was established at $P < 0.05$.

**OUTCOMES**

**Stage I: Development of the Peripheral Brain and Performance Criteria**

Performance criteria for compilation of the peripheral brain were developed by the fifth-year therapeutics students and categorized as: (i) retrieving information; (ii) organizing information; (iii) processing information; and (iv) relating information (see Appendix A). Each criterion was defined and then used to evaluate the PB on a 0 to 3 scale, with a score of zero indicating that the criterion was not met within the section of the PB, and a score of 3 indicating the criterion was consistently evident in the construction of the PB. Using this evaluation system, a total score of 12 points was possible on each PB assessment.

**Stage II: Application of Performance Criteria**

Assessments of the fifth-year students’ PBs prepared without the guidance of criteria and feedback, were compared to assessments of the fourth-year students’ PBs, which were constructed with the aid of criteria and feedback. The median scores of summative PB assessments for each group were compared. Fifth-year students scored lower on the summative (or final) assessment than fourth-year students, 7.55 (CI 25 percent = 6.36, 75 percent = 9.74) versus 9.92 (CI 25 percent = 9.00, 75 percent = 10.50), respectively ($P < 0.001$). This was not surprising since the use of criteria and feedback three times during the semester effected improvement in the fourth-year students’ PBs during the semester. That is, scores improved from a median score of 7.00 (CI 25 percent = 5.50, 75 percent = 8.30) on the first (formative) assessment to a median score of 9.00 (CI 25 percent = 8.00, 75 percent = 10.25) on the second assessment and to 9.92 (CI 25 percent=9.00, 75 percent=10.50) on the third (summative) assessment ($P < 0.001$). The students’ score distributions of their PB assessments are shown in Figure 2. As noted in the ‘process’ section above, fifth-year students received no formative assessment during the semester.

**Stage III: Evaluation of the Impact of Peripheral Brains on Student Performance**

The PB allowed instructors to increase the number of questions requiring higher order thinking during exams.

**Part I.** After introduction of the PB system, the percentage of exam questions requiring level 3 thinking skills (analysis, synthesis, evaluation) rose to 94 percent, compared to only 44 percent prior to implementing the PB system (Table I). Instructors shifted exam emphasis to questions requiring analysis, synthesis, and evaluation skills because they recognized that recall and comprehension questions would be readily answered by referring to the PB, particularly if students had effectively compiled their PB. Students’ mean scores on exams, however, did not change appreciably despite the fact that the majority of exam questions were clearly more complex than prior to implementation of the PB system (average exam scores were 73 percent pre-PB versus 75 percent post-PB, $P = n s$). In other words, although the exams became more difficult, students’ grades remained the same.

**Part II.** When this inventory of exam questions was conducted again in the fourth- and fifth-year classes, it was noted that instructors continued to require more practice of
higher order thinking skills than lower order thinking skills (33-82 percent versus 3-47 percent, respectively) (Table II). Students’ mean exam scores during this period ranged between 65 and 84 percent. Unintentionally, there was one exam that consisted of only 33 percent Level 3 (analysis, synthesis, evaluation) questions and 67 percent Levels 1 and 2 (recall, comprehension, application) questions. Students scored the highest on this exam, achieving a class average of 84 percent. Based on this observation, student exam scores were analyzed to determine if there was any association between exam performance and the percentage of Level 1 and Level 3 questions. The results demonstrate an inverse correlation between student exam performance and number of higher order (Level 3) thinking questions ($r = -0.78$, $P < 0.05$) and a direct correlation between student exam performance and number of lower order (Level 1) thinking questions ($r = 0.84$, $P < 0.05$) (Figures 3 and 4).

**DISCUSSION**

Students often have difficulty retaining basic pharmacotherapeutic information and then applying it to case-related homework and exams. Thus, we developed the PB system to assist students in accomplishing this task. If done correctly, as students retrieve, organize, process and relate therapeutic information while constructing their PB, they are also retaining and learning the therapeutic principles to apply in didactic and experiential settings. In assembling the PB, each student retrieves and comprehends material from primary, secondary, and tertiary literature. Then, each student must analyze (for example, compare and contrast drug classes), synthesize (for example, design an algorithm for the treatment of a disease), and organize the information for

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**Fig. 3. Student performance based on Bloom’s taxonomy.**

**Fig. 4. Student performance based on Bloom’s taxonomy.**

**Fig. 5. Results of student surveys.**

**Student Perception of PB (Figure 5)**

Approximately 95 percent of the fourth-year class rated their PB as a good reference. Sixty per cent of students indicated that use of the PB promoted less rote memorization of vast amounts of course-related material, such as equations, dosage forms, and lab values. However, only a minority (38 percent) of students thought that the PB helped them achieve a passing score on examinations. Students also stated that the time required to compile the PB was excessive and that there was a tendency to become overly dependent on its contents.
quick retrieval within the PB. In short, students are processing the information and not just transcribing it. Thus, it is intended that these pocketbooks de-emphasize the process of temporarily memorizing large volumes of information, while instead fostering greater retention of important therapeutic information and developing higher order thinking. Indeed, students stated that they spent less time memorizing equations, dosage forms, and lab values, which created increased opportunities to process more meaningful information.

The PB not only can serve as a reference throughout the therapeutics course sequence but is intended to be used during subsequent clinical clerkships. The carefully prepared PB can promote an added measure of confidence when students are confronted with new or unexpected therapeutic problems in the classroom or patient care setting. However, the PBs are not intended to serve as a substitute for a student’s general knowledge base, clinical assessment skills, or ability to formulate a therapeutic plan. Thus, students who relied excessively on the PBs indicated that they were hampered during exams and homework cases, probably because they attempted to use the PB as a surrogate for thinking and problem solving skills. With or without the aid of the PB, students will achieve desired ability outcomes only by acquiring knowledge, repetitively practicing skills, and developing the attitudes needed to render pharmaceutical care.

The use of performance criteria to guide preparation of the PBs allowed students to assess their own, as well as peers’, PBs. This approach provided explicit feedback on the PB assignment for the purpose of effecting improvement in student performance. It also placed emphasis on what the student achieved rather than on what the instructors provided. In this project, those students who participated in a performance criteria-directed process produced PBs that reflected enhanced higher order thinking skills, as evidenced by their higher summative assessment scores.

With implementation of the PB system, instructors altered exam content to require higher order thinking skills more frequently. When comparing the student performance on these exams (post-PB) versus pre-PB exams that tested advanced thinking skills less frequently, the mean exam scores were surprisingly similar. We had incorrectly anticipated that student performance would decline due to increased exam complexity. Although there are no data addressing this issue in the pharmacy literature, Staskun and Daniels found that students required to function at higher cognitive levels had a lower passing percentage on chemistry exams(12). In a chemistry course of nursing and occupational therapy students, 88 percent of students passed (mean score 66.3 percent) the mid-year examination compared to only 42 percent passing (mean score 49 percent) the end-of-year exam. Retrospectively, the authors analyzed their exam questions based on Bloom’s Taxonomy. The end-of-year exam consisted of a higher percentage of advanced level thinking skills than the mid-year exam (42.1 vs 12.5 percent Level 3, 33.6 vs 30.8 percent Level 2, 24.3 vs 56.7 percent Level 1, respectively). Thus, students performed better on the exam that included a greater number of lower taxonomic questions. In contrast to Staskun and Daniels’ study, our students constructed and employed the PB, which one might argue assists students in developing higher order thinking skills and problem-solving capabilities.

The PB is not the only determinant of successful performance of course ability outcomes. The PB itself contains primarily factual information, which is only one component of an ability outcome; students who lack skills will not perform well regardless of the quality of their PB. This might explain why students taking examinations that emphasized higher order thinking skills did not perceive the PB to be a particularly helpful resource during the test-taking process. Successful test performance required students to effectively use the information contained in the PB. However, the preparation of the PB required students to organize and synthesize information; these skills were reinforced by systematic feedback from peers and instructors, using explicit performance criteria. Homework and classroom case studies that required students to use PB content provided opportunities for repeated practice of critical thinking.

CONCLUSION

Peripheral brains serve as useful references and provide a system for students to systematically process therapeutic information. Explicit performance criteria and continuous assessment and feedback enable the student to improve the quality of the PB and to become more effective in clinical problem-solving. The use of the PB during examinations allowed instructors to emphasize higher order thinking skills and provided more opportunities for students to practice and be assessed on the ability outcomes. We conclude that preparation of the PB serves as an effective learning tool for improving students’ higher order thinking skills in pharmacotherapy courses.

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References


(8) Alverno College, Student Assessment-as-Learning at Alverno College, Alverno College Institute, Milwaukee WI (1994).


APPENDIX A. PERIPHERAL BRAIN PERFORMANCE CRITERIA

Date ______________ Name _____________

Substantiation of all scores must be supported by written comments.

0 Use of the criteria is not evident in any section of the peripheral brain (i.e., < 25 percent of the brain meets the criteria)

1 Use of the criteria is seldom evident in the construction of the peripheral brain (i.e., approximately half of the brain meets the criteria)

2 Use of the criteria is occasionally evident in the construction of the peripheral brain (i.e., > 75 percent of the brain meets the criteria)

3 Use of the criteria is consistently evident in the construction of the peripheral brain (i.e., > 75 percent of the brain meets the criteria)

Retrieving information 0 1 2 3

Selects information from curricular areas (e.g., anatomy, pathophysiology, pharmacology, microbiology, therapeutics)

Utilizes more than one source of information throughout the curricular areas (i.e., does not rely only on course notes)

Selects both textual and graphical (e.g., algorithms, charts, diagrams, pictures) materials

Comments: Average:

Organizing information 0 1 2 3

Arranges topics (e.g., angina, gout, hypertension) logically for quick retrieval (e.g., alphabetically, tabs, index)

Presents information in a clear, concise, and legible fashion

Comments: Average:

Processing information 0 1 2 3

For each topic, extracts and condenses pertinent information from articles/handouts, texts without relying on verbatim (xeroxed) material

Illustrates similarities and differences of drug classes with respect to mechanism of action, pharmacokinetics, adverse effects, drug interactions, contraindications (e.g., beta blockers vs calcium channel blockers vs ACE inhibitors)

Illustrates similarities and differences of agents within drug classes with respect to mechanism of action, kinetics, adverse effects, drug interactions, contraindications (e.g., nifedipine vs verapamil vs amlodipine)

Comments: Average:

Relating information 0 1 2 3

Illustrates the relationship between the pathophysiologic mechanisms of the disease and the drug therapy by mapping, diagraming, etc.

Comments: Average:

Total Points (Sum of averages) ______________/12

APPENDIX B. BLOOM'S TAXONOMY (11)

Knowledge The recall of specifics or related facts. This process emphasizes the psychological process of remembering. It includes the knowledge dealing with specific facts, trends, classifications and theories as well as procedures employed in a specific subject field. Knowing the major risks for a patient with a particular illness would be an example of this level.

Comprehension This represents the lowest level of understanding. Comprehension involves making use of an idea without necessarily relating it to other material or realizing its full implication. Examples are interpreting the meaning of a graph or predicting the continuing spread of a contagious disease.

Application The use of abstractions or principles to solve problems. These may be in the form of generalizations or theories which must be remembered and applied. Examples include applying scientific terms discussed in a paper to other situations, or solving health problems using scientific knowledge.

Analysis The breaking down of complex information into simpler parts to understand how they are related or organized. Analysis is intended to clarify and provide an understanding of the interactions between elements. An example would be relating a patient’s previous symptoms to a current medical condition.

Synthesis The process of combining concepts to constitute a new whole. This includes creating completely new products such as writing a composition or developing a differential diagnosis for a patient.

Evaluation Making value judgements based on some given criteria or standard. Comparing two different medical procedures regarding patient prognosis is an example of this level.