Assessment in Medical Pharmacology: Designing MCQs to Assess a Student's Type-1 Problem-Solving Skills

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Over the past decade, in response to the reports on the General Professional Education of the Physician[1] [GPEP report] and Educating Medical Students: Assessing Change in Medical Education-The Road to Implementation[2] [ACME-TRI], medical schools have embarked on major curricular changes in medical education. The focus of these curricular changes has included [i] a reduction in the number of didactic lectures, [ii] an increase in small group discussions and computer-assisted instruction, and [iii] introduction of problem-based learning [PBL]. While much attention has been directed to the ***process*** by which medical students are educated, comparatively little attention has been devoted to how we ***assess*** medical student performance.

Assessment is said to drive student learning and define the curriculum[3]. Inherent in this notion is that student learning behavior is driven by success ["Skinnerian" academics]. Success in education, in turn, is largely measured by performance on examinations. Consequently, if students know that their success on examinations rests entirely on rote recall of facts, they will adopt a surface [or instrumental] learning style that relies purely on memorization. On the other hand, if students are required to integrate, interpret, and apply information they will adopt a strategic [or achieving/conceptual] learning style in order to derive the highest degree of success.

In 1985, prompted by this common sense doctrine of learning, coupled with obvious recognition that patients do not present to the physician with a self-determined diagnosis, cause and 'most' appropriate treatment, we began assessment of student performance in the CNS section of our Medical Pharmacology course by employing multiple-choice questions [MCQs] designed to assess a student's Type-1 problem-solving skills. In such questions, all elements to solve the problem are embedded in the question, but the student must apply and integrate his or her foundation of knowledge to arrive at a logical conclusion. The correlate of this type of problem solving in the clinical practice of medicine is the strategy of hypothesis formation employed in "pattern recognition."

Testing Cognitive Domains: The Purpose and Nature of Type-1 Problem-Solving MCQs

To fully understand and appreciate the nature of MCQs aimed at testing a student's Type-1 problem-solving skills, it is useful to apply Bloom's taxonomy, which classifies levels of intellectual behavior important in learning into domains[4]. In this context, student learning is viewed in a hierarchical fashion. In ascending order of complexity, cognitive intellectual behavior can be classified into rote recall, comprehension, application, analysis, synthesis, and evaluation. Type-1 problem-solving MCQs are designed to test the higher-order abilities [Figure 1].

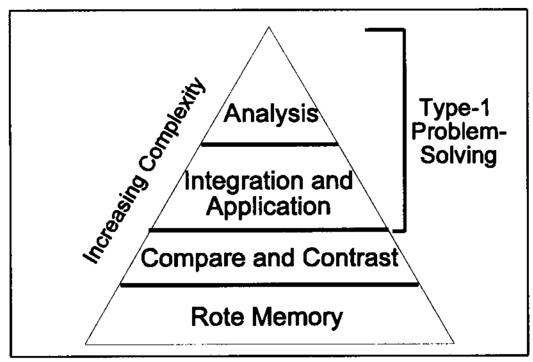


Figure 1: Hierarchical Cognitive Domains and Type-1 Problem-Solving MCQs

The application of this hierarchy in developing MCQs can be seen in the questions depicted in Figure 2 dealing with carbamazepine-induced syndrome of inappropriate antidiuretic hormone. In Panel A, the student is simply asked to recall, from a list of adverse drug reactions, one that is associated with the use of carbamazepine. This rote presentation is typical of the type that students are asked in their basic science courses [M-I / M-II years]. In Panel B, the student is asked to classify [i.e., Which agents are useful in treating bipolar disorder?] and identify [i.e., Of the drugs used to treat bipolar disorder, the use of which is associated with the development of SIADH?]. This is also a commonly used format to assess student performance in their M-I / M-II years. Panel C is representative of a Type-1 problem solving MCQ in a clinical vignette presentation. Here students must integrate information from their basic sciences courses [i.e., recognize the presentation of SIADH and bipolar disorder] and apply their knowledge in pharmacology [compare and contrast agents used in the treatment of bipolar disorder] to arrive at a logical conclusion.

Panel A: Rote Memory

The use of carbamazepine has been associated with the development of:

1. hypothyroidism.
2. **syndrome of inappropriate antidiuretic hormone [SIADH]**.
3. nephrogenic-diabetes insipidus.
4. leukocytosis.
5. tardive dyskinesia.

Panel B: Compare and Contrast

A female patient treated for bipolar disorder develops SIADH. She is ***most*** likely being treated with:

1. valproic acid.
2. chlorpromazine.
3. **carbamazepine**.
4. tranylcypromine.
5. clomipramine.
6. lithium.
7. clonazepam.

Panel C: Integration and Application

J.M, a 30-year-old female, presents with complaints of nausea, headache, dizziness, fatigue and confusion. These symptoms have become more prominent over the past 2 weeks. **Laboratory results** [+ normal values] were:

$Na^+_{[SERUM]}$ 110 mEq/L [135-145 mEq/L]
$Cl^-_{[SERUM]}$ 88 mEq/L [100-108 mEq/L]
Osmolality:
Plasma - 236 mOsm/kg [275-295 mOsm/kg]
Urine - Inappropriately concentrated relative to serum Na^+

Other tests and examination revealed no evidence of dehydration with normal renal, adrenal and thyroid function. **Pertinent Medical History**: Six weeks ago J.M. began appropriate drug therapy for a disorder characterized by hyperactivity, insomnia, loquaciousness with racing thoughts and an unusually "happy" mood. Therapy with which drug would be ***most*** consistent with J.M.'s medical history and presenting symptoms?

1. Valproic acid
2. Chlorpromazine
3. **Carbamazepine**
4. Tranylcypromine
5. Clomipramine
6. Lithium
7. Clonazepam

Figure 2: MCQs Designed to Test the Various Levels of the Cognitive Domain

As the various reforms in medical education in most medical schools are towards inter- or multidisciplinary versus traditional discipline-based curricula, the assessment using the construct of Panel C is consistent with these initiatives. Furthermore, since cognition and memory are enhanced when information is provided in meaningful context[5] [i.e., for medical students in a clinically relevant manner], the use of integrated vignettes can reinforce a student's learning by fostering practice in the retrieval of this relevant information. In the past five years, USMLE-Step 1 has increased the use of this type of format and presentation. While assessment using this type of MCQ is increasing in our institution, it is far from being the "norm" in the M-I and M-II years [anecdotal communication from students].

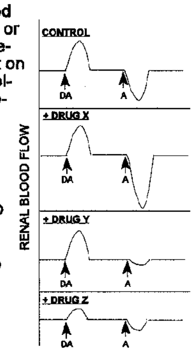
While the use of the clinical vignette format adds the "flavor" of clinical relevance in assessing the students knowledge base, a variety of alternative formats [Figure 3, e.g., graphical, tabular, figures and diagrams] are also useful to assess a student's Type-1 problem solving skills. These formats generally extend the assessment of a student's cognitive skill to include analysis. This would represent the upper limit of cognitive intellectual activity that can effectively be assessed using MCQs.

	Urinary Electrolytes				Blood
Drug	Na^+	K^+	Ca^{2+}	HCO_3^-	ELECTROLYTE IMBALANCE
A	↑	↑	↔	↑↑↑	Acidosis
B	↑↑	↑	↓	↑ or ↔	Alkalosis
C	↑↑↑	↑↑	↑	↔	Alkalosis
D	↑	↓	↔	↔	Acidosis

From the information provided in the table shown above, Drug B **most** likely:

1. **inhibits NaCl cotransport in the early distal tubule.**
2. binds to intracellular receptors in the early collecting duct thereby increasing transciption of mRNA for Na^+ channels.
3. inhibits Na^+ / K^+ / 2 Cl^- co-transport in the ascending loop of Henle
4. inhibits carbonic anhydrase in the proximal tubule.
5. blocks Na^+ channels in the late distal tubule and early collecting duct.

The figure to the right depicts changes in renal blood flow [RBF] in response to dopamine [DA, low dose] or amphetamine [A] in the absence [CONTROL] or presence of DRUGS X, Y and Z. In view of their effect on DA- and A-elicited alteration in RBF, which of the following correctly matches these drugs with an appropriate clinical use?



	DRUG X	DRUG Y	DRUG Z
1.	Panic disorder [D/O]	Tourette's D/O	Delusional D/O
2.	Depression	Schizophrenia	Obsessive Compulsive D/O
3.	Huntington's Disease	Depression	Post-Hallucinogen Perception D/O
4.	**Depression**	**Chronic Pain**	**Huntington's Disease**
5.	Schizophrenia	Depression	Panic D/O

Figure 3: Testing of Analytical Skills Using Type 1 Problem-Solving MCQs

The Process: The Development and Approach to Designing Type-1 Problem-Solving MCQs

While we now assess medical student performance in our medical pharmacology course using type-1 problem-solving questions, consisting largely of the clinical vignette-type format, there can be some initial trepidation on the part of faculty who were trained outside of a medical curriculum. The "I'm not a physician; where do I begin?" response is common. This apprehension on the part of faculty can be overcome through the use of a multitude of clinical resources. Some examples of very useful sources of information for the development of clinical vignettes that have been employed by our faculty are:

- Textbooks
  Applied Therapeutics: The Clinical Use of Drugs, Young and Koda-Kimble [6th Ed., 1995]
  Harrison's Principles of Internal Medicine, Isselbacher, et al., [14th Ed., 1998]
  Pharmacotherapy. A Pathophysiologic Approach, Dipiro, *et al.*, [3rd Ed., 1995]
- Grand Rounds
- Clinical Clerkship Rotation
- Attending select lectures in other M-I and M-II courses that relate to their material in pharmacology.

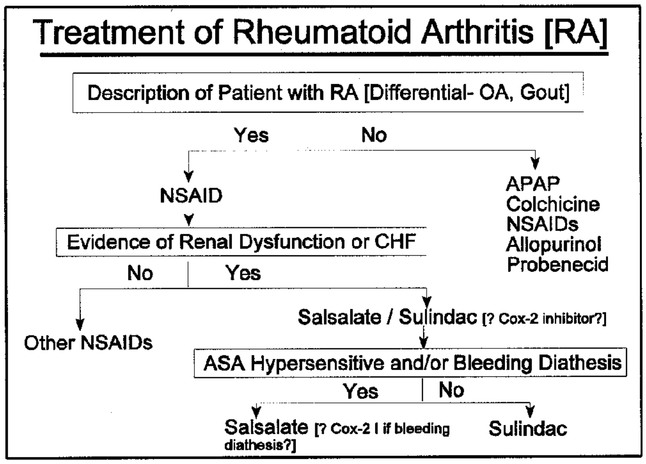


Figure 4: An Therapeutic Algorithm for the Clinical Managment of Rheumatoid Arthritis

After acquisition of the appropriate clinical background, the development of a clinical vignette is facilitated by constructing a therapeutic algorithm or knowledge map. An example is shown for the treatment of arthritis where 'therapeutics' is used to assess the clinically relevant knowledge base of the student [Figure 4]. The vignette will have a patient presenting with arthritis and the student must be able to differentiate rheumatoid from osteo- or gouty arthritis. The appropriate differential will assess a student's understanding of therapeutic options. The pre-existing health status of the patient will assess the student's understanding of the basic pharmacological difference(s) among these therapeutic options. Many clinical vignettes assessing type-1 problem-solving skills can be constructed from such an algorithm or knowledge map [e.g., Figure 5].

In developing type-1 problem-solving MCQs for assessment of M-1 and M-11 student performance, the following caveats are offered:

- Anticipate a significant commitment of time in developing such questions. Maximize your efforts by constructing stems which are multi-functional, i.e., ones which provide a framework for developing alternative MCQs.
- make certain that the question is complete and unambiguous but avoid "red-herring" information in the stem. The ideal clinical vignette MCQ should be answerable without looking at the options.

- Avoid the common temptation to write rote questions cloaked in superfluous clinical vernacular [e.g., Figure 6 being no different that the straight forward presentation in Figure 2, Panel B]. While the clinical presentation of the question may be more interesting for some students to read, a vignette written in this manner does not extend the level for assessing a student's cognitive skills.

M.A.D., a 44-year-old female, presents with complaints of morning stiffness persisting for 2-3 hours, joint pain, weight loss and fatigue. These symptoms have been present for the past 4 months. **Physical Examination** revealed: bilateral, symmetrical swelling, tenderness and warmth of the metacarpophalangeal [MCP] and proximal interphalangeal joints [PIPs] of the hands and the metatarsophalangeal [MTP] joints of the feet. **Laboratory** and **Radiological** findings: normal except for a slightly elevated erythrocyte sedimentation rate and a serum creatinine of 2.5 mg/dL [normal, 0.6-0.9]. X-ray films were negative for tophi and showed soft tissue swelling of the hands and feet. **Pertinent Medical History**: M.A.D. is aspirin hypersensitive. In light of her medical history, the ***most*** appropriate treatment of her present condition would be:

1. Probenecid
2. **Salsalate**
3. Colchicine
4. Sulindac
5. Allopurinol
6. Acetaminophen

Figure 5: Differential Assessment of Rheumatoid Arthritis and Its Treatment

Assessment Using Type-1 Problem-Solving MCQs: Optimizing Student Success

This author's [C.W. Davis] use of type-1 problem-solving MCQs for the assessment of student performance in CNS pharmacology was met with substantial *ex post facto* rancor on the part of the students when first introduced. Despite measures to assist and prepare students for this type of exam in 1985, the average score on that exam, remains today the lowest of any in our course. Additionally, there was clearly a slow "learning curve" in order for students to achieve a comparable level of performance on this exam to the others in the course [Figure 7]. A gradual conversion to the use of type-1 problem-solving MCQs on all examinations was begun in the early 1990's. This transition was introduced in a more methodical manner using the experience gained on the CNS exam in order to optimize the opportunity for student success. Most of the methods employed to accomplish this have focused on strategies for facilitating the student's ability to apply and integrate information [consistent with our "Doctrine of Fairness" in student assessment].

Areas of this focus have included:

- Course restructuring to make it more:

  [i] conceptual and less encyclopedic[6].
  [ii] internally integrative and progressively comprehensive.
  [iii] vertically integrative [i.e., sequenced with other M-II courses].

- Faculty presentations which:
  [i] present the basic pharmacology [e.g., general principles related to drug action, mechanisms, side-effects, drug interactions, precautions, contraindications, etc.] in a context relevant to the practice of medicine.
  [ii] incorporate case-studies [mini-lecture, group conference or written].

- Providing students with an idea of expected standard[s] of performance through:
  [i] use of written goals and objectives for each section of the course.
  [ii] access to the past 3 years of examinations. In some cases, annotated answers are provided which detail the requisite "plan of attack" to arrive at a logistical conclusion. These are "invaluable" learning devices for students as they prepare for their own exams.

- Assisting students at "high risk" in developing the req uisite learning skills.

In addition, we believe that each 50 question sectional examination should be "knowledge-limited" and not time-limited. Consequently, students are allowed [and occasionally require] 3 hours to complete each examina-

J.M., a 30-year-old female, presents to your office with the complaints of nausea, headache, dizziness, fatigue, and confusion. After extensive laboratory tests you conclude she is experiencing SIADH secondary to therapy for bipolar disorder. This patient is ***most*** likely being treated with:

1. valproic acid
2. chlorpromazine
3. **carbamazepine**
4. tranylcypromine
5. clomipramine
6. lithium
7. clonazepam

Figure 6: Factually straight-forward information in a clinical vignette format.

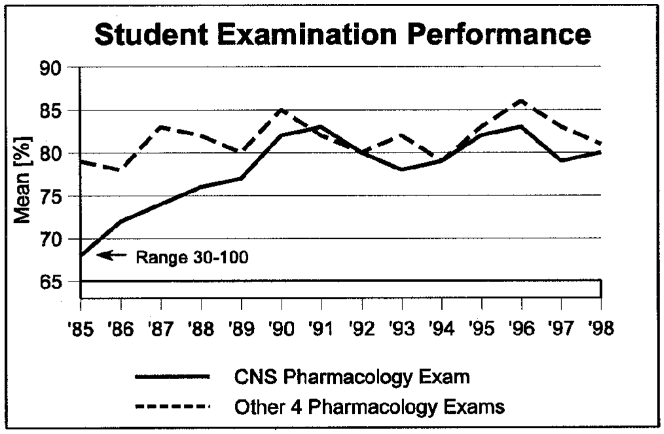


Figure 7: Annual Student Performance on Medical Pharmacology Exams

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Outcome Analysis: Perspectives on the Use of Type-1 Problem-Solving_MCQs

The use of type-1 problem-solving MCQs to assess student performance in our Medical Pharmacology course has brought about an increased focus on transmitting content relevant information to our students. This has generated a higher level of enthusiasm for learning, as the student perceives the information as highly relevant to the practice of Medicine

More importantly, such assessment has modified student learning behavior. A high level of success is no longer possible using surface learning [i.e., rote memory, compartmentalization of information, etc.] but now requires a strategic learning style [i.e., conceptualization, application, disciplinary and multi-disciplinary integration and analysis]. As a manifestation of the "raising the bar" for learning, students often remark that "Pharmacology exams are the first exams in medical school where we have to think." and "Pharmacology is the toughest course in the first two years." Despite these comments, student satisfaction has increased based upon data from course and post-graduate year-1 [PGY-1] evaluations in which Medical Pharmacology consistently receives the highest rating of all M-I and M-II courses and among the highest of all required courses, including clerkships.

The most obvious potential disadvantage in assessment of student performance using this type of MCQ involves the increase in faculty time commitment, *sans* reward. This is minimized in our course through the responsibilities of the course director. First, the internal and vertical integration of the course is handled entirely by the director who is responsible for a comprehensive content knowledge in the entire course. This minimizes the time that faculty spend availing themselves to the aforementioned sources of information. Furthermore, the director's responsibility for teaching pharmacology in the M-III year and residency training facilitates faculty in the area of personal development in the area of clinical application of the basic pharmacology. The greatest time investment for individual faculty is in the development of novel type-1 problem-solving MCQs. Again, the course director has minimized this burden by [i] providing intradepartmental faculty development in the area of writing MCQs, [ii] assisting faculty in generating ideas for development of questions which involve integration and application of basic pharmacology, [iii] reviewing/editing all questions, subject to their approval, and [iv] the actual writing of their questions. Obviously the requisite time expenditure for creating novel MCQs could be minimized if students are not allowed access to the examination questions after taking the examination. If one opts for the latter, our experience suggests that the students should be provided with either a representative set of questions as an example of the faculty member's standard of expectation or a robust set of learning objectives internally consistent with the nature of the outcome assessment as recommended by the Association of American Medical Colleges [AAMC][7].

From the students' perspective, there can be an initial dissatisfaction stemming from their relative lack of success on these examinations. This was particularly evident when we first introduced these examinations, as students had no "frame of reference" for assessment using type-1 problem-solving MCQs. By providing students with past examinations, they were made aware of the standard of expectation and could effectively adopt a different learning style. In effect, from 'old' examinations, students "learned how to learn" and this has translated into limited dissatisfaction [i.e., greater success, refer to Figure 7]. However, about 5% of the students still do not achieve satisfactory success [a 'C' or better grade] in our course. This represents more unsatisfactory grades in Medical Pharmacology than all other M-11 courses combined.

Summary

Improvement in the quality of medical education involves both changes in curriculum design and outcome assessment. While the recognition of the desired attributes that a student should possess upon graduation and learning objectives so derived has focused much attention on curricular renewal in medical education, comparatively little attention has been devoted to the method[s] used to assess whether these outcomes are being achieved.

Domains of intellectual behavior important for the practice of medicine include cognitive, affective and psychomotor learning. In the basic science years, the cognitive learning domain is the primary intellectual learning behavior and is typically assessed by using MCQ-format examination. While it is desirable that a medical student would possess the requisite skills to reason deductively and develop appropriate management strategies, the use of traditional MCQs which are simply rote recall of facts fail to assess these abilities. The design and use of MCQs to test type-1 problem-solving measures the higher level cognitive capabilities of a student required for these skills. As examinations constitute the classic paradigm for operant conditioning, the use of MCQs to test type-1 problem-solving skills fosters the development of these reasoning capabilities and modifies learning behavior. Consequently, they can impact the quality of medical education, as much or more so, than modification of curricular design.

References

1. Muller, S. Physicians for the Twenty-First Century: Report of the Project Panel on the General Professional Education of the Physician [GPEP] and College Preparation for Medicine, J. *Med. Educ.* 59, Part 2, November 1984.

2. ACME-TRI Report: Educating Medical Students, Association of American Medical Colleges [AAMC], 1992.

3. Newble, D.I. and Jaeger, K. The Effect of Assessments and Examinations on the Learning of Medical Students, *Med. Educ.* 17:165-171, 1983.

4. Bloom, B.S. Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook 1: Cognitive Domains, David McKay Company, New York, 1959.

5. Regehr, G and Norman, G.R. Issues in Cognitive Psychology: Implications for Professional Education, *Acad. Med.* 71:988-1001, 1996.

6. Davis, C.W. and Allen, D.O. Modification of a Traditional Pharmacology Curriculum, *The Pharmacologist* 40:28-30, 1998.

7. The Medical School Objectives Writing Group. Learning Objectives for Medical Student Education-Guidelines for Medical Schools: Report I of the Medical School Objective Project [MSOP]. *Acad. Med.* 74:13-18, 1999.