Driving Deeper Learning by Assessment:

An Adaptation of the Revised Bloom's Taxonomy *for Medical Imaging in Gross Anatomy*

Andrew W. Phillips, MD, MEd, Sandy G. Smith, PhD, Christopher M. Straus, MD

Rationale and Objectives: As medical imaging continues to grow as a central modality by which physicians of all specialties visualize anatomy, so, too, is its role in medical student education. However, no study to our knowledge has attempted to categorize the necessary cognitive skills. Here, we assess a tool to identify those skills and their possible hierarchical nature that reflects deeper understanding of radiological anatomy.

Materials and Methods: We adapted the revision of Bloom's *Taxonomy of Educational Objectives* to create examination questions and teaching points for normal radiological anatomy in a medical anatomy course in 2008. All six previously established levels of cognitive processes were adapted, ranging from Remembering to Create. Reliability and validity were assessed.

Results: Of 102 eligible students, 98 (98%) consented to participate, and 108 examination questions were assessed. Cronbach α assessing reliability ranged from poor (.197) to moderate (.571) with most categories being moderate. Score means for the levels of cognitive processes were statistically distinct [$F(4, 102) = 180.63$, $P < .001$] and tended to decrease as the level of cognitive process increased [Spearman $\rho(5) = -.800$, $P = .104$], consistent with a valid hierarchical structure.

Conclusions: A radiological anatomy adaptation of the revised taxonomy demonstrated generally adequate reliability and acceptable validity to establish evaluations that test different depths of cognitive processes. This is a critical first step to create a fundamental curricular tool by which medical imaging education—both normal and pathological—may be taught and assessed in the future.

Key Words: Radiological anatomy; medical student education; medical education; anatomy; evaluation; curriculum; assessment; medical reasoning.

Radiology as a specialty is at a crossroads concerning its role in undergraduate medical education. National-level discussions of what constitutes core medical imaging knowledge, who is most effective at instruction, and whether a radiology clerkship should be required are all under consideration. Moreover, the Alliance of Medical Student Educators in Radiology recently published a recommended radiology curriculum for US medical schools and is currently creating a national database of radiology test questions for students in both preclinical and clinical courses (1). It is critical during this fundamental juncture that medical imaging assessments are validated, test a range of skills and depth of knowledge, and promote effective learning to optimize patient care in the long term (2).

It is well established in both the general higher education and medical education communities that assessment is one of the strongest influences on learning (3–8). For example, a statistically significant difference in student study patterns was observed recently when a UK program changed medical student examination emphases (6). In addition, the benefits of aligning curricular components, from course objectives to assessments, have long been well established in the education community (4,9).

Creating a formal tool by which to differentiate and identify medical imaging questions is a relatively new concept. Thus far, the limited studies have focused on degree of difficulty in diagnostic imaging interpretation but did not explore the cognitive skills required to interpret the images (10,11). On a fundamental level, medical image interpretation centers on understanding anatomy, such as can be demonstrated by imaging examinations. Thus, it is plausible that specific cognitive processes may be commonly applicable in this process regardless of the body region, imaging modality, or training level (preclinical or clinical).

Acad Radiol 2013; 20:784–789

From the Stanford University, Department of Emergency Medicine, Stanford, California (A.W.P.); Pritzker School of Medicine, University of Chicago, Chicago, Illinois (S.G.S., C.M.S.); and Department of Radiology, University of Chicago, 5841 S. Maryland Ave, MC 2026, Chicago, IL 60637 (C.M.S.). Received November 7, 2012; accepted February 1, 2013. Financial support: This study was supported internally by the Pritzker School of Medicine and the Department of Radiology, both of the University of Chicago, Chicago, IL. **Address correspondence to:** C.M.S. e-mail: cstraus@uchicago.edu

http://dx.doi.org/10.1016/j.acra.2013.02.001

TABLE 1. Six Categories of the Cognitive Process Dimension with Radiological Anatomy Examples

Category	Cognitive Process	Radiological Anatomy Example
Remember*	Recognizing	Recognize the orientation of the image.
	Recalling	Recall structures: point and label.
Understanding†	Interpreting	"In which direction was this chest x-ray taken?"
	exemplifying	Give examples of markers to distinguish anatomical structure location.
	Classifying	"Classify the categories into which the different shades of gray in a radiograph belong."
	Summarizing	"Write a short summary of structures deviated in a tension pneumothorax."
	Inferring	"Infer which structure shown would most likely be impacted by ischemia to the SMA [superior mesenteric artery]."
	Comparing	Compare pathology to normal images.
	Explaining	"Explain why this axial chest CT slice is at T4."
Apply‡	Executing	"What arteries does a RBC [red blood cell] traverse in traveling from the heart to the right brachial artery?"
	Implementing	N/A
Analyze§	Differentiating	Distinguish the different parts of structures, such as "label the ascending aorta in an AP [anteroposterior] x-ray."
	Organizing	Organize these CT [computed tomographic] slices in correct order.
	Attributing	N/A
Evaluate¶	Checking	"Is this lung size normal?"
	Critiquing	"How could patient position cause air in the peritoneal cavity to not be visualized in this (KUB) image?"
Create**	Generating	"What could cause this acute structural abnormality?"
	Planning	With a chest x-ray: "In what plane (coronal, sagittal, or axial) would you best visualize the left main bronchus?"
	Producing	N/A

N/A, not available.

Adapted from *ANDERSON\ KRATHWOHL\AIRASIAN\CRUIKSHANK\MAYER\PINTRICH\RATHS\WITTROCK, A TAXONOMY FOR LEARNING, TEACHING, AND ASSESSING: A REVISION OF BLOOM'S TAXONOMY OF EDUCATIONAL OBJECTIVES, ABRIDGED EDITION, 1st,©2001*. Printed and Electronically reproduced by permission of Pearson Education, Inc., Upper Saddle River, New Jersey.

††A similar—but not identical—image may have been previously viewed.

*Remember: "Retrieve relevant knowledge from long-term memory."

†Understanding: "Construct meaning from instructional messages."

‡Apply: "Carry out or use a procedure in a given situation."

§Analyze: "Break material into constituent parts and determine how parts relate to one another and to an overall structure or purpose."

¶Evaluate: "Make judgments based on criteria and standards."

**Create: "Put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure."

Anderson and colleagues recently created a major revision of Bloom's seminal *Taxonomy of Educational Objectives* (12) that has been well validated (13–16) and incorporates both contemporary learning theories and refined cognitive process descriptions. The revised taxonomy (Table 1) differentiates hierarchical levels of cognitive ability ranging from simple recall (Remembering) to synthesis of knowledge to create a new concept (Creating). An important departure from the original taxonomy is the fundamental assumption that higher cognitive processes can be achieved without mastery of subordinate processes.

We therefore sought to apply the revised taxonomy to radiological anatomy as an initial effort to describe a formal taxonomy of medical imaging interpretation. Based on the aforementioned previous research, we hypothesized that discrete, hierarchical levels of cognitive processes would emerge to describe different levels of learning medical imaging concepts. We further hypothesized that mean examination scores would inversely correlate with level of cognitive process required.

MATERIALS AND METHODS

Participants and Study Design

Study protocols were granted exemption status from the University of Chicago Institutional Review Board. All 102 students enrolled in the first-year medical student anatomy course at the University of Chicago, Pritzker School of Medicine were eligible to participate. Students who wished to participate provided written, informed consent. Participation was blinded to faculty and had no bearing on course evaluation.

The course represented the first basic science class of their medical school curriculum, and thus students had received no formal prior anatomy or radiology education at our institution as part of their degree program. The gross anatomy course was co-taught by radiology and anatomy faculty with the aid of anatomy graduate students and upper classmen (second- and fourth-year) medical students.

The anatomy course required both gross and radiological components over six total modules taught consecutively