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ABSTRACT

This paper describes a work in progress on a second edition of "Taxonomy of Educational Objectives, The Classification of Educational Goals, Handbook I: Cognitive Domain," also known as "Bloom's Taxonomy" (B. Bloom and others, Eds., 1956). The new edition will be grounded in the collective wisdom of the original "Handbook," but will incorporate contextual and conceptual changes that have taken place since its publication. Like the original, the new handbook will contain five chapters describing the background, structure, and implications of the revised taxonomy; but the second section, instead of containing sample objectives and test items, will contain vignettes illustrating applications of the revised taxonomy in schools. The new edition will make a distinction between knowledge as the process of recall and knowledge as the content that is recalled, designating the first category of the cognitive process dimensions as "remember." Cognitive processes will be conceptualized somewhat differently, with the acknowledgment of a broader range of contextual factors that influence learning and the use of cognitive processes. Three implications of the expected changes are noted. First is the importance of diversity in educational assessment. Another aspect is considering the relationships among tasks in designing assessment; and still another is the realization that the structure of the taxonomy is more likely to be evident in the scoring rubric than in the tasks themselves. The new "Handbook" is a work in progress, and the revised taxonomy has yet to be completed. It is not yet known how learning, curriculum, instruction, and assessment will interface in the final version. (SLD)

Rethinking Bloom's Taxonomy: Implications for Testing and Assessment

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In November, 1995, a group of cognitive psychologists, curriculum theorists, and testing and assessment specialists met in Syracuse, New York, to discuss the desirability of revising the *Taxonomy of Educational Objectives, The Classification of Educational Goals, Handbook I: Cognitive Domain*, also known as Bloom's taxonomy.[2] After considerable discussion, the group, which was jointly chaired by David Krathwohl, one of the authors of the *Handbook*, and Lorin Anderson, one of the editors of the 1995 volume, *Bloom's Taxonomy: A Forty Year Retrospective,* decided to proceed with a second edition.[3] This new edition would be grounded in the collective wisdom embodied in the original *Handbook,* but would incorporate contextual and conceptual changes that have taken place since its publication in

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[1] I wish to express my appreciation to my friend and colleague Peter Airasian for his careful review of an earlier draft of this paper. His comments and suggestions were extremely useful in the revision.

[2] Throughout this paper the term *"Handbook"* is used to refer to the actual volume, while the term "taxonomy" refers to the classification system.

[3] In addition to David Krathwohl, Syracuse University, and Lorin Anderson, University of South Carolina, the group consists of Peter Airasian, Boston College; Jean Clandinin, University of Alberta; Michael Connelly, Ontario Institute for Studies in Education; Linda Crocker, University of Florida; Kate Cruikshank, Indiana University; Richard Mayer, University of California, Santa Barbara; Paul Pintrich, University of Michigan; Jim Raths, University of Delaware; Bill Rohwer, University of California, Berkeley; and Merle Wittrock, UCLA.

1956.

Decisions also were made about the organization of the revised *Handbook*. Like the original, the new edition would have two parts. The first would include five chapters describing the background, structure, and implications of the revised taxonomy. In a departure from the original *Handbook*, the second part would contain vignettes illustrating applications of the revised taxonomy in schools and classrooms (rather than sample objectives and test items).

For the next fifteen months group members have prepared drafts of both parts of the revised handbook.[4] The group will met again in February, 1997, to review the drafts, make additional writing assignments, establish a time line for completion of a draft of the entire volume, and discuss the internal and external review procedures for the completed draft. A contract with Addison Wesley Longman, the publisher of the original *Handbook,* has been signed, with a manuscript due on or before February, 1998. The purposes of this paper are to describe the major changes that we envision in the *Handbook* and to discuss the implications of the revised *Handbook* for tests and other forms of assessment. At this point in the developmental process, this paper is best viewed as a "work in progress."

Major Changes

[4] The five chapters are tentatively entitled "A taxonomy of learning for teaching" (Chapter 1), "The role of objectives in education" (Chapter 2), "The knowledge base for learning and teaching" (Chapter 3), "The cognitive processes of learning and thinking" (Chapter 4), and "Applications of the taxonomy: Policy, curriculum, and assessment" (Chapter 5).

In preparing the new *Handbook, we* have tried to achieve a balance between the familiar and the novel. The purpose of the revised *Handbook* as well as its size and format are quite similar to the original. Furthermore, while the number of taxonomic categories is likely to be slightly more than the original, every attempt has been made to relate the new categories and category labels to the old. At the same time, however, there are several key differences between the original *Handbook* and its revision. Three are discussed below.

Two Dimensions Rather than One

The categories of the original taxonomy -- knowledge, comprehension, application, analysis, synthesis, and evaluation -- were ordered along a single dimension. This dimension was conceived by the authors as a hierarchy of increasingly complex "student behaviors which represent the intended outcomes of the educational process" (Bloom *et al.*, 1956, p. 12). Because the authors defined these intended behaviors in terms of "mental acts or thinking" (p. 12) we have chosen to use the phrase "cognitive processes" to refer to this dimension.

As we discussed this dimension, it became apparent that knowledge, the least complex category in the taxonomy, could have two quite different definitions. First, knowledge could involve the ability to recall specifics and universals, methods and procedures, or patterns and structures (Bloom *et al.*, 1956, p. 201). Using this definition, knowledge is the *ability to recall.* A second definition of knowledge appears in an analogy made by the authors of the original *Handbook.* "If one thinks of the mind as a file, the problem in a knowledge test situation is that of finding in the problem or task the appropriate signals, cues, and clues which will

most effectively bring out whatever *knowledge is filed or stored*" (Bloom *et al.*, 1956, p. 201) (emphasis mine). Using this definition, knowledge is *what is recalled;* the terminology, facts, conventions, trends and sequences, classifications and categories, criteria, methodology, principles and generalizations, and theories and structures that define an academic discipline, subject matter, or course of study (Bloom *et al.*, 1956, pp. 201-204).

These two definitions correspond to the longstanding distinction between process and content. The ability to recall is a cognitive process, while the knowledge to be recalled is the relevant content. These two conceptions of knowledge can also be seen in the separation of "knowledge" and "intellectual abilities and skills" (i.e., comprehension, application, analysis, synthesis, and evaluation) in the original *Handbook*.

In light of this dual meaning, we have chosen to separate the two definitions of knowledge - knowledge as the process of recall vs. knowledge as the content which is recalled. To clarify this distinction, we have replaced "knowledge" with "remember" as the first category on the cognitive process dimension. Our second (and new) dimension consists of the major types or categories of knowledge. Thus, the revision will permit the "crossing" of each cognitive process with each type of knowledge (e.g., recall of methods, application of methods, comprehension of principles, analysis of principles).

Consider, for example, the following educational objective: "The student will distinguish factual from normative statements." The verb "distinguish" provides the clue to the intended cognitive process. "Factual statements" and "normative

statements" represent the content to be known or used. Most, if not all, educational objectives can be stated in the form: The student will VERB the NOUN PHRASE, where the verb corresponds with the cognitive process (dimension 1) and the noun phrase corresponds with the relevant knowledge (dimension 2).

Expansion of The Knowledge Dimension

Despite numerous attempts to sort and classify knowledge, it should be pointed out that the meaning of the term "knowledge" is not always clear. Krathwohl (1985) has differentiated knowing from knowledge. Knowing is idiosyncratic. Based on our unique experiences we each come to know certain things; that is, we believe certain things to be true. I may "know," for example, that a "daddy long legs" is a true spider (it isn't), that blue is my favorite color (it is), and that homogeneous grouping of students for instructional purposes is wrongheaded (it may or may not be). This idiosyncratic knowing corresponds to our personal beliefs.

Knowledge is consensual knowing (Krathwohl, 1985). That is, if a group of people shares a common set of beliefs, their collective "knowings" become "knowledge." If this is the case, two major issues arise. First, who are the members of the group? This question raises the social and cultural aspect of knowledge. Cults often hold to a shared set of beliefs that others in the larger community may not accept as "truths." Second, what means are used by the group to determine when knowing become knowledge? Appeals can be made to authority, tradition, consensus, and evidence. Within the scientific community, (1) consensus is formed around evidence, (2) evidence is presented to and screened

by the community, and (3) the evidence must meet certain criteria (e.g., validity, reliability) (Krathwohl, 1985).

Carroll's (1985) distinction between concepts and meanings is quite similar to the difference between knowing and knowledge. Based on their experiences, people form concepts. Concepts are "abstracted and often cognitively structured classes of 'mental' experience learned by [people] in the course of their life histories" (p. 233). In order to communicate about our unique concepts, we give them names (that is, words in a particular language that enable people to share not only their experiences but the way in which they classify or categorize them). Meanings, then, require shared concepts associated with common names. Or, in Carroll's words, a "'meaning" of a word is ... a societally-standardized concept, and when we say that a word stands for or names a concept it is understood that we are speaking of concepts that are shared among the members of a speech community" (p. 240).

These distinctions between knowing and knowledge and between concepts and meanings have led us to expand the knowledge dimension beyond the purely academic one envisioned by the authors of the original *Handbook*. In addition to academic knowledge, two additional knowledge categories have been developed: strategic/motivational and social/cultural.[5] The first, strategic/motivational,

[5] In fairness to the authors of the original *Handbook*, it must be pointed out that they recognized the role of society and culture in determine what constitutes knowledge. "There is also a geographical and cultural aspect to knowledge in the sense that what is known to one group is not necessarily known to another group, class, or culture. ... (K)nowledge is always partial and relative rather than inclusive and fixed (p. 32).

recognizes the importance of knowing as a legitimate educational goal. This category contains what has been termed metacognition and includes the learning strategies students employ, the links they make between their efforts and their accomplishments, and their perceptions of themselves as people and as learners. The addition of the second category, social/cultural, reflects our appreciation of the cultural-specificity of knowledge. It also recognizes the role of social learning theory in explaining how students learn.

Finally, the academic category tentatively contains six subcategories: facts, concepts, principles or generalizations, procedures and methods, strategies and plans, and theories and belief systems. These subcategories are quite similar to those included in the original *Handbook*. They are consistent with other classification systems (e.g., Gagne, 1965; Merrill, 1971). For example, concepts and principles are also in the Gagne scheme (with facts classified as "verbal information"). The subcategories also are consistent with recent developments in cognitive psychology (e.g., Anderson, 1983; Ohllson, 1994). Facts, concepts, and principles can be classified as "declarative knowledge," while procedures/methods and strategies/plans represent "procedural knowledge."

Conceptualization of Cognitive Processes

Cognitive processes are the means by which knowledge is acquired or constructed and used to negotiate the problems and demands of everyday life. In the original *Handbook*, several terms and phrases were used to refer to cognitive processes. The most common is "intellectual abilities and skills," which are defined as "organized modes of operation and generalized techniques for dealing

with materials and problems" (Bloom *et al.*, 1956, p. 204).

Despite the similarity in terminology, there are several differences in the conception of cognitive processes underlying the two versions of the taxonomy. These differences lie in the relationships among the cognitive processes, the generalizability of cognitive processes, the contextualized nature of cognitive processes, and the role of cognitive processes in problem solving.

Relationships among the cognitive processes. Two basic relationships among cognitive processes are explicit in the original taxonomy: increasing complexity and a cumulative hierarchical structure. In the original, each step from knowledge through evaluation was hypothesized to represent increasing cognitive complexity. Thus, knowledge was the least complex cognitive process while evaluation was the most complex. Moreover, the authors of the original *Handbook* hypothesized that the six categories formed a cumulative hierarchy. That is, each lower taxonomic category was necessary but not sufficient for cognitive processing at each higher category. In the words of the authors, "the objectives in one class are likely to make use of and be built on [those] found in the preceding classes on the list" (Bloom *et al.*, 1956, p. 18).

In the revised version, we have chosen to retain the principle of increasing complexity but to reserve judgment on the cumulative hierarchical structure. Like the original, the cognitive process categories in the new taxonomy are arranged from least complex to most complex. Unlike the original taxonomy, however, we would not argue that the categories form a cumulative hierarchy **in all cases**. Rather, the extent to which a cumulative hierarchy is present depends on a series

of factors, several of which are described below.

Generalizability of the cognitive processes. The authors of the original *Handbook* made several claims for the generalizability of the taxonomy. They assumed that, essentially, the six taxonomic levels would be observed across subject matters, levels of education (elementary, high school, college), and schools. "Thus, a single set of classifications should be applicable in all these instances" (Bloom *et al.*, 1956, p. 12). Substantial research leads us to question the validity of this assumption since current evidence suggests that knowledge acquisition or construction often is domain-specific (Hirschfeld and Gelman, 1994). That is, different academic disciplines and/or types of problems may require and/or support different cognitive processes Furthermore, the structure of a particular domain will determine in part whether the taxonomy forms a cumulative hierarchy (as mentioned earlier).

The contextualized nature of cognitive processes. In contrast to the original, the revised *Handbook* recognizes a broader range of contextual factors which influence the learning and use of cognitive processes. Two primary examples are the knowledge, abilities, attitudes, and interests brought by the student to the learning situation (collectively known as the history of the learner) and the conditions under which the learning is expected to occur (e.g., the activities in which students are expected to engage, the ways in which the material to be learned in represented to the students).

The authors of the original taxonomy recognized the importance of taking into account the student's learning history if objectives were to be properly classified.

Having recognized this as a "classification problem" (Bloom *et al*, 1956, p.16), however, they proceeded in Part 2 of the *Handbook* to provide general examples of objectives and test items for each taxonomic category. Furthermore, the situated nature of cognitive processing and knowledge acquisition/construction were not addressed in the original *Handbook*. For example, while textbooks may summarize a body of knowledge as a set of propositions, the knowledge which particular individuals "possess" may include representations of a more personal and concrete nature. For such persons, narratives may be more informative and meaningful than propositional logic.

This recognition of the importance of contextual factors in classifying cognitive processes led to the restructuring of Part 2 of the original *Handbook*. Rather than including large numbers of objectives and test items, Part 2 of the revised *Handbook* will contain a relatively small number of classroom vignettes. These vignettes are intended to provide the contextual basis necessary for properly classifying the educational objectives while at the same time illustrating applications of the taxonomy in the areas of teacher planning, instruction, and assessment.

The role of cognitive processes in problem solving. Although mentioned throughout the original *Handbook*, problem solving plays a much larger role in the revised version. That problem solving is an essential objective of education was obvious to the authors of the original *Handbook* (Bloom *et al.*, 1956, p. 38). They went on to argue that

intellectual abilities and skills are the fundamental tools of problem solving. They stopped short, however, of describing the relationship between specific cognitive processes and problem solving. There are, for example, no illustrative objectives and test items pertaining to problem solving. Rather, Part 2 of the *Handbook* gives

the impression that problems, like objectives, can be classified in terms of a single cognitive process. Thus, we have problems which require primarily application, problems which require primarily analysis, and so on.

Our view of problem solving is quite different. While we agree that cognitive processes are the fundamental tools of problem solving, we argue that virtually all problems require the use of several cognitive processes. Analysis is frequently needed to determine the type of problem being posed. Translation (comprehension) permits a visual representation of the problem to be made. Remembering enables the required knowledge and information to be readily available. Synthesis can organize the knowledge and information in an effective and efficient way. Evaluation helps determine the reasonableness or appropriateness of the proposed solution. In combination, the set of cognitive processes used to solve a problem is the *solution strategy*.

As students engage in problem solving they must reflect on their actions, monitor their progress, and correct their mistakes. These activities emphasize the role of metacognition in problem solving. In fact, it is metacognition that most clearly differentiates problem solving from application. In application, once a solution strategy has been given, selected, or designed, the steps are followed in a rather "blind," routine manner. Little "thinking about thinking" is evident. In contrast, metacognitive activities enable students to make decisions "midstream." They may decide to change strategies, redo particular steps, or start over.

Implications for Testing and Other Forms of Assessment

As differences between the original *Handbook* and the revised version have

emerged in our writing and discussion, our attention has begun to turn to the implications these changes have for educational policy, curriculum and instruction, and testing and other forms of assessment. For example, legislators and policy makers in the United States have become enamored with standards. Unfortunately, the term "standard" is ambiguous. It can refer to (1) what students should know and be able to do or (2) how well students should know or be able to do it. The first meaning is similar to that traditionally associated with the concept of educational objective; the second, to the traditional meaning of performance standard. Thus, the taxonomy must be structured and the *Handbook* written in such a way that these critical differences are emphasized and understood.

Similarly, in terms of curriculum and instruction, a major problem is the impact of contextual factors on taxonomic classification and instructional delivery (as mentioned earlier). It is one thing to say that the taxonomic level of a particular educational objective depends to a great extent on the prior learning experiences of the students. It is quite another to deal with the practical implications (and applications) of this statement. One implication, for example, is that in a classroom of students with diverse learning histories, quite different cognitive processes will be needed to attain the same objective. Teasing out these varying cognitive processes and knowing for which students which set is most appropriate is no easy matter.

Because the audience for whom this paper is written consists of educators with expertise in assessment, the remainder of the paper will focus on three implications the aforementioned changes in the *Handbook* have for testing and other forms of assessment They are as follows. First, diversity in educational

assessment is essential. Second, considering the relationships among tasks is important in designing assessment strategies and techniques. Third, when performance assessment is used, the structure of the taxonomy is more likely to be evident in the scoring rubric than in the tasks themselves. Before I expand on these three implications, I would like to comment briefly on the structure of assessment as we have come to understand it.

The Structure of Assessment

All forms of assessment, including testing, have four essential components: (1) a set of tasks to which students are to respond; (2) the responses students make; (3) the rules and procedures for scoring (or otherwise evaluating) the responses; and (4) the way in which the scores (or evaluations) are interpreted. The **tasks** may consist of questions to be answered, incomplete sentences to be completed, problems to be solved, or instructions given to perform some activity (e.g., "Write an essay which ... ", "Draw a diagram showing ... "). Possible **responses** to the assigned tasks include selecting the correct or best answer or solution, supplying an answer or solution, or performing some activity. The scoring or evaluation **rules** and **procedures** may be emboddied in a scoring key, a scoring rubric, ratings scales, checklists, or a computer algorithm. Finally, the scores or evaluations may be **interpreted** in terms of the scores or evaluations received by other students (norm-referenced), some domain of learning or achievement represented by the tasks (domain-referenced) , or some level(s) of expected performance on the tasks (criterion-referenced).

Although all forms of assessment contain these four components, the way

in which we talk about assessment often tends to emphasize a particular one. The phrase "norm-referenced test," for example, refers to a way of interpreting assessment results. Similarly, "objective test" refers to scoring rules, "multiple-choice test" to the form of responses, and "critical thinking test" to the tasks presented to the students.

Quite clearly, there are connections among the four components, so they can be combined in various ways. For example, traditional critical thinking tests rely on multiple-choice items which are scored objectively and which are interpreted in a norm-referenced manner. However, it is possible to conceive of critical thinking tests which require written responses which are scored using a scoring rubric and which are interpreted in a criterion-referenced fashion. In fact, if each of the four components had only two alternatives (e.g., lower-order vs. higher-order tasks, select vs. supply responses, scoring keys vs. scoring rubrics, and criterion-referenced vs. norm-referenced interpretation) a total of 2^4 or 16 possible combinations would be possible.[6]

The emphasis in the original *Handbook* was on multiple-choice test items.[7]

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[6] While not all of these combinations appear on the surface to be reasonable, they should not be rejected out of hand. For example, multiple-choice items tend to be associated with scoring keys. However, if a decision is made to weight the choices in terms of their correctness or reasonableness, then a scoring rubric seems more appropriate.

[7] At its initial meeting, David Krathwohl informed the group that the multiple-choice format was chosen purposefully in order to illustrate its flexibility and applicability. That is, the authors were interested in demonstrating how multiple-choice items could be used to assess different objectives.

With the exception of the synthesis and evaluation objectives,[8] all sample items were multiple-choice. Within the context of a multiple choice item, the task is included in the stem (i.e., the introductory material, question, response options); the proper response is for the student to select the correct, best, or most appropriate option; and the scoring is done with a scoring key or by a computer program.

With respect to interpretation, the authors of the original *Handbook* clearly favored a domain-referenced approach. While this is implicit throughout the volume, they make it explicit at one point.

> The emphasis in the Handbook is on obtaining evidence on the extent to which desired and intended behaviors have been learned by the student. It is outside the scope of the task we set ourselves to properly treat the matter of determining the appropriate value to be placed on the different degrees of achievement of the objectives of instruction. ... This is matter of grading or evaluating the goodness of the performance (Bloom *et al.*, 1956, p. 13).

Neither additional discussion nor any examples of interpretation appear in the *Handbook*.

Because of the reliance on multiple-choice test items, most of the information pertaining to the relationship between items and taxonomic categories was inherent in the task itself. That is, to properly classify a test item, one only had to attend to the task presented to the student (particularly the question asked or the direction given). Tasks that asked students to select the proper definition of a term from among four possible definitions were judged to be appropriate for assessing

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[8] For the non-multiple-choice test items, there is a brief discussion of the criteria to be used in evaluating student performance and the possible use of checklists and rating scales in conducting these evaluations. However, no illustrative checklists or ratings scales are included in the *Handbook*.

knowledge objectives (Bloom *et al.*, 1956, p. 79). Similarly, tasks in which students were given a first line of a hypothetical poem and instructed to complete the verse were judged to be appropriate for assessing synthesis objectives (Bloom *et al.*, 1956, p. 179).

Having described the four primary components of assessment and discussed the perspectives of the authors of the original *Handbook* in terms of these components, I will now turn to the three aforementioned implications that the changes in the *Handbook* will likely have for testing and other forms of assessment.

Diversity in Educational Assessment

Despite the almost exclusive emphasis on multiple-choice items, the authors of the original *Handbook* did realize that direct assessment[9] of objectives at the highest levels of the taxonomy required what is now called "performance assessment" (cf. Bloom *et al.*, 1956, pp. 178, 181-182, 199). Rather than simply shift from multiple-choice tests to performance assessment, however, the revised *Handbook* will emphasize the need for multiple forms of assessment. Stated simply, we believe that the diversity of cognitive processes represented in the taxonomy requires a comparable diversity of assessment strategies and techniques.

The task confronting test and assessment specialists, then, is not to advocate particular assessment strategies and techniques, but to determine the

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[9] Bloom *et al.* (1956) suggested that multiple-choice and short-answer formats were at best indirect assessments of synthesis and evaluation objectives. And whether they actually were indirect assessments was "an empirical matter" (p. 176).

assessment strategies and techniques that are most appropriate for particular cognitive processes, either individually or collectively. The four components described earlier can serve as a framework for making this determination. What **tasks** would be most appropriate for each taxonomic category as well as for problems that require multiple taxonomic categories? What types of **responses** would provide the the most useful information? What **scoring rules** are most reasonable? What **interpretations** are most relevant?

In this regard, consider the application level. Appropriate tasks would include those that (1) describe a situation in which the knowledge being taught is applicable but one which has not previously been encountered by the students, (2) make explicit the knowledge to be applied, and (3) ask students to apply the knowledge to the situation. Appropriate responses could include those that require students to (1) write the steps they used in their application and the answer they derived or (2) when given a choice of several sequences of steps select the one they would use in situation and then determine the answer. Appropriate scoring rules may be in the form of a scoring rubric (for writing the steps) or an answer key (for selecting the steps). Finally, the most appropriate interpretations depend primarily on the purpose for which the assessment is being made (i.e., the decisions to be made based on the results). If the teacher is deciding whether to move on to another objective or unit, a criterion-referenced interpretation may be more appropriate. If, on the other hand, the teacher is deciding which students to nominate for an award, a norm-referenced interpretation is likely to be more appropriate.

Such an analysis would emphasize the differences among the various cognitive processes. For example, if a task requires that students determine the appropriate knowledge to use in a given situation (rather than being told the appropriate knowledge to use), then analytic processes would be called upon. Similarly, if a task mirrors the situations used in instruction, then students would only have to recall the steps that were used and the answer that was derived (assuming, of course, they have not forgotten what transpired during instruction).

The revised *Handbook,* then, will emphasize the need to consider the four components -- tasks, responses, scoring rules and procedures, and interpretation -- in terms of the cognitive processes and knowledge being assessed. In this way, guidelines for designing appropriate assessment strategies and techniques for different cognitive processes and knowledge types can be developed. Furthermore, since assessment strategies and techniques are generally more concrete than are statements of objectives, testing and assessment specialists can contribute to an increased understanding of the cognitive processes and knowledge types included in the taxonomy.

Assessment Instruments and Individual Tasks

The design of a test or any other assessment instrument generally begins by specifying one or more domains. The domains may be subject matters (e.g., a spelling test) or educationally-relevant divisions of subject matters (e..g., mathematical computation, mathematical concepts, mathematical problem solving). The domains also may correspond to educational objectives (e.g., solve problems involving applications of Boyle's law).

Once a domain has been specified, tasks traditionally are selected by virtue of their association with the domain. All the tasks on a spelling test must be words. Students may respond by spelling the words correctly, identify correctly spelled or misspelled words, or correct misspelled words. Similarly, an assessment of student ability to solve problems applying Boyle's law typically contains *n* tasks, each of which ask students to solve a given problem. The point to be made here is that tasks are generally selected by virtue of their relationship to the domain, not their relationship with one another.

The revised taxonomy adds another criterion for the selection of tasks for inclusion on assessment instruments. Namely, the relationships among the tasks should be considered. In this way, information pertaining to the structure of the taxonomy as it relates to the domain being assessed is available.

As has been mentioned, problem solving involves a series of cognitive processes. To assess problem solving, then, an assessment instrument should include tasks which represent the component cognitive processes and requisite content. Consider the previous example involving Boyle's law. While the emphasis is on problem solving, the assessment instrument can include tasks designed to assess a variety of cognitive processes.

Tasks representing the lowest cognitive process, remember, may include those pertaining to the law itself as well as the conditions under which the law holds (e.g., relatively low pressures, constant temperature). At the next level, tasks assessing students' conceptual understanding (e.g., pressure, volume, proportion, inverse) would be relevant. At the third level, the students may be given tasks in

which they are provided with numerical values for temperature, pressure, and volume at one point in time and numerical values for temperature and pressure at a second point in time, and asked to find the volume on the second occasion.[10] At the fourth level, the tasks may require that students determine whether the information given in the problem situation justifies the use of Boyle's law. If not, students may be asked to determine the appropriate law to be applied. Finally, there may be one or two tasks which give students a problem situation along with the work of two hypothetical students in solving the problem. The (real) students would be asked to critique each of the hypothetical students' solution strategies, making corrections as necessary and appropriate.

Note that the content underlying the assessment all pertains to Boyle's law, a principle. The basic facts and concepts underlying the law are assessed. In addition, students are asked to differentiate Boyle's law from other laws which, because of their relation to Boyle's law, may cause confusion among students (e.g., Gay-Lussac's or Charles' law).

Performance Assessments, Scoring Rubrics, and the Taxonomy

There is at least one case where the taxonomic categories and their relationships are more likely to be evident in the scoring rules and procedures rather than the tasks themselves. This is the case of performance assessment.

With performance assessment, scoring rules and procedures are typically in

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[10] Variations on this "theme" are possible. For example, students can be asked to find the pressure on the second occasion. Similarly, a possible response option can be "not applicable" if the temperature on the two occasions is significantly different.

the form of scoring rubrics. These rubrics provide two important components of assessment: scoring "rules" (namely, the criteria for assessing the responses made to a task or set of tasks), and interpretation (namely, words or phrases denoting levels of proficiency). The problem solving rubric shown in Figure 1 is an example.

The criteria are inherent in the "excellent" rating (i.e., correct solution, clear explanation, simplified diagrams, problem identification, and lack of computational errors). The levels of proficiency are evident in the differences among the four ratings (e.g., 5 correct vs. 3-4 correct vs. 2 correct vs. 0-1 correct).

The incorporation of the taxonomic structure could be done without a great deal of difficulty. In fact, the seeds are already there. "Lack of computational errors" may represent remember or apply (depending on the complexity of computation required).[11]

Excellent (4)

Correct solution for all 5 problems
Explanation is clear
Simplified diagrams
All aspects of problem identified
No computational errors

Good (3)

Correct solutions for 3-4 problems
Explanation is clear
Diagrams simple but may have errors

[11] Once again, we see the importance of prototypical assessment tasks is determining the appropriate placement of objectives and criteria in terms of the taxonomic categories. The role of testing and assessment specialists in bring precision to the taxonomy cannot be underestimated.

Parts of problems not explained A few computational errors

Satisfactory (2)

Correct solutions to 2 problems
Explanation unclear
Diagrams unclear
May have major computational errors

Unsatisfactory (1)

0-1 correct solutions
No explanations
No diagrams or messy
Major computational errors

Figure 1. A scoring rubric for problem solving

Source: Thompson, M. & Thomason, J. (1996). *Achievement and learning-focused lessons*. Boone, NC: Learning Concepts, Inc.

"Clear explanation" and "simplified diagrams" would likely represent comprehend. "Problem identification" probably represents analyze (or perhaps comprehend). Finally, "correct solution" represents apply. Rather than attempting this exercise after the fact, however, it would be far better to begin the development of the scoring rubric with the taxonomy in mind.

Closing Comments

The most important comment to make in closing is to reiterate that this is work in

progress. We do not know exactly how many categories of cognitive processes the revised taxonomy will contain nor do we know the labels we will use to denote them. We do not know the classifications and terminology of the knowledge dimension. We do not know how learning, curriculum, instruction, and assessment will interface in the final *Handbook*.

Because this is work in progress, reactions, criticisms, and particularly suggestions are very timely. We have approximately one year to complete our work. My hope is that we are sufficiently far along to stimulate some useful thinking, while at the same time being able to meet our deadline. This paper represents my attempt to synthesize the "collective consciousness" at this point in time.

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