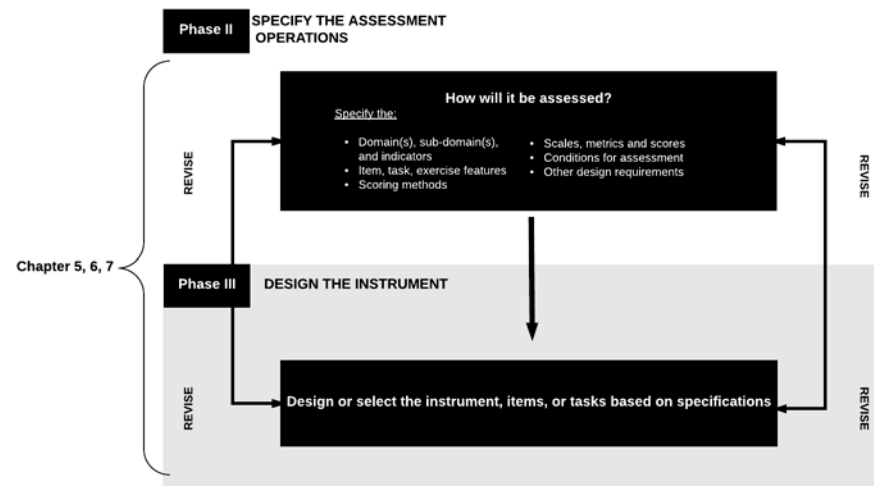*Designing Assessments for Multidisciplinary Constructs and Applications: A User-centered Methodology*

Chapter 5- Supplements
Tables, Boxes and Figures

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Note: See Figure 1.6 for the complete model

Figure 5.1 Connecting Chapter 5 to the Process Model and the rest of the book.

Mathematical Patterns Assessment: Domain Specifications

Outcomes: M16   Identify and generalize number patterns to
                          discover relationships and express them mathematically.
                 M1   Use mathematical problem-solving strategies.
                 M7   Demonstrate a number sense.
                 M12   Understand formal geometric principles.

Embedded Indicators:
    Level 1   Identify, continue and explain simple repeating patterns
                 involving letters, shapes or numerals (e.g.,
                 ABCABCAB…).
    Level 2   Identify, continue and explain growing patterns involving
                 geometric shapes, symbols, numerals, and rudimentary
                 arithmetic/geometric concepts.
    Level 3   Identify, continue and explain growing patterns involving
                 beginning level arithmetic operations, geometric concepts,
                 and graphs (e.g., 3 (+2), 5 (+2), 7 (+2)…).
    Level 4   Identify, continue and explain growing patterns involving
                 intermediate level operations, geometric concepts, and
                 graphics (e.g., multiplication, fractions, odd numbers,
                 prime numbers (e.g., 5 (x 5), 25 (x 5), 125…).
    Level 5   Identify, continue and explain growing patterns involving
                 advanced intermediate operations and spatial concepts
                 (e.g., division, squares, square roots, embedded squares).

Response Format Specifications:

Completion items combined with short answer, paper and pencil tasks

Continued.

Sample Task at Level 3:

Directions. Items 1-4 are part of the
same question and will be scored
together. They deal with patterns.

1. See this number pattern
   below. Continue it by
   filling in the last two
   blanks.

   15, 20, 25, ___, ___.

2. What math rule did you use
   to find the next numbers in
   the above pattern?
   [Space provided]

3. Suppose the same pattern
   was continued by someone
   up to 75. What two
   numbers come next?

   75, ___, ___.

4. Explain how you knew the
   answer to #3.
   [Space provided]

Figure 5.2 *Assessment design specifications for constructed response tasks*

Continued.

Conditions Specifications:

Context-dependent, developmentally-ordered multi-part items on test.
No more than 5 numbers and 3 blanks in each item.
Items with no more than 4 parts.
Examinees allowed about 5-10 minutes for each task.
This is a group-administered, classroom assessment.

Materials Specifications:

Tests with 3-15 assessment task(s), with 3 tasks at each of five developmental levels, randomly mixed. Answer sheet provided, with pencils, as needed.

Scoring Method Specifications:

Classroom assessments:
Analytic rating scale for teacher uses.
End-of-year assessment:
4-point, holistic rubrics for teacher or administrative uses. All raters trained in use of rubrics. Anchor papers and error charts provided.

Target Student Specifications:

Age 7-12 years

Assessment Purposes:

Formative and summative decision-making in schools

Scoring Rubric:

3 Fills in blanks and answers questions to illustrate the correct math rule and gives a clear explanation OR gives an alternate, reasonable answer. Shows strong understanding of concepts with little or no errors

2 Fills in blanks and answers questions to illustrate math rule OR gives explanation to show understanding of rule. Shows some understanding, but makes some errors

1 Show limited understanding, but attempts to answer using some math patterns knowledge. Makes several or repeated errors.

0 No response or unreasonable response.

Figure 5.2 *Assessment design specifications for constructed response tasks*

Response shows that student:	Rating Scale		
	2 Yes, no errors	1 Yes, minor errors	0 No answer/ major errors
1. Identified the pattern			
2. Continued the pattern as required			
3. Used a reasonable and effective strategy to solve the patterns problem			
4.Made use of multiplication and/or addition facts appropriately			
5. Computed correctly with place values			
6. Showed grasp of relevant terms and language (patterns, increasing series, repeating series)			
7. Understood item instructions			
8. Showed mastery of basic number sense, geometry and prerequisite skills required			
9. Gave a mathematically comprehensible explanation			
TOTAL SCORE			

Figure 5.3 Analytic rubric for a constructed response task on number patterns

Box 5.1 Contrasting approaches to item design to tap a higher order outcome in Long Division

Culminating Outcome: (The students) Solve real world problems using long division with one or two digit divisors, express the remainder as a decimal or fraction, and explain the solution in their own words -*Higher Order Thinking*

Traditionally-designed Multiple Choice Item
1. Coconut cookies come in packets of **12**. I would like to give 1 cookie to each 5th grader at our school to celebrate the last day of school. There are **216** 5th graders at our school. **How many packets of cookies should I buy** so that **every 5th grader gets at least 1 cookie**? Choose the best answer.

    a. 12
    b. 15
    c. 18 *[Correct answer]*
    d. 20

Cognitively-informed Item Series:

Directions: Read the story problem below and answer questions 1-5.

Coconut cookies come in packets of **12.** To celebrate the last day of school, I would like to give 1 cookie to each 5th grader at our school. There are **219 5th graders** at our school. **How many packets of cookies should I buy** so that **every 5th grader gets 1 cookie**?

1. Write in your own words what the problem is asking. Then, show your plan to solve this problem. [Space provided]
2. Which of these operations is in your plan? Circle all that apply.
    a. Addition
    b. Subtraction
    c. Multiplication
    d. Division
    e. Something else (explain)
3. Now, set up and solve the problem. Show all your work. [Space provided]
4. Your answer? _____
5. Remainder? _____
6. Write the remainder as a <u>decimal</u> of the quotient._____.
7. Write in your own words what the answer and remainder mean <u>in the story problem</u>. [Space provided]

Box 5.2. *Traditional multiple choice items versus cognitively-informed item series in Long Division*

Traditional structured response items in Long Division for Grade 4 students	Item series in Long Division for grade 3-5 students: Probing items designed to map knowledge structures of students on a learning continuum

1. Do the problem below, and choose the best <u>answer</u>.
 	
$5\overline{)175}$
 	
a. 21
b. 25
c. 31
d. 35[correct answer]
e. None of the above
 	
2. The <u>remainder</u> in the problem in Question 1 is___? Circle the best answer.
 	
a. 0 [correct answer]
b. 1
c. 3
d. 5
e. None of the above
	Directions: For Items 1-2, choose the best answer. For Items 3-5, write your answer in your own words.
	
	$5\overline{)175}$
	
	1. The math problem above is asking me to :
	   a. Multiply 5 and 175
	   b. Divide 175 into 5 equal parts
	   c. Subtract 5 from 175
	   d. Add 5 and 175 to find the sum
	   e. Do something else (Explain)
	2. Another way in which you can say what the problem is asking, is: Find out how many groups of 5 there are in 175.
	   a. True
	   b. False
	3. Solve the problem, showing all <u>steps</u> of your work, <u>the answer</u> and <u>remainder</u>, if applicable. [Space provided]
	4. If you did not find a <u>remainder</u> after you completed the steps, what is the reason for that? Explain your answer in your own words. [Space provided]

Box 5.3
Embedding metacognition and self-evaluation items during assessment to match indicators in the Long Division domain

A culminating learning outcome in a Long Division for Grade 3-5 students and targeted Cognitive Level[1]	Excerpted indicators, targeted Cognitive Levels[1] and item series

1.0 (The student) Solves real world problems using long division with one or two digit divisors, and explains solutions -*Higher Order Thinking*[1]	1.5. (The student) Evaluates the correctness of solutions when applying long division procedure - *Higher Order Thinking* [1]
	    1.5.1. Identifies errors or misapplications of steps - *Application*[1]
	    1.5.2 Self-corrects errors, such as, computation or place value errors, during process - *Application*[1]
	    1.5.3 Checks answers using a backwards operations or other reasonable procedure (e.g., multiplying divisor with quotient and adding remainder, as applicable) - *Complex Procedural Skills*[1]
	
	Constructed response task series designed to tap into Indicators 1.5
	Directions:
	  1. I began to do the following problem but know I have made some mistakes. Please find and circle all my mistakes.
	
	        610
	    9) 552
	     -54
	       12
	        9
	        3
	       -0
	        3 Remainder
	
	  2. Show me how I could fix my mistakes by re-doing the problem. Show all your work.
	    [Space provided for correct solution]
	
	  3. How did you check different parts of the answer in Question 1? List each step and say what it helped you do.
	    [Space provided]

Box 5.4
A self-assessment checklist in long division for Grade 3-5 students: Encouraging
metacognition and self-reflection habits

Cognitive Indicators

I can:
-Say in my own words what the long division problem is asking me to do
-Read a story problem and set up the long division and/or <u>other</u> operations needed to solve it
-Identify the "dividend" and "divisor" in a long division problem; identify the "quotient" and "remainder" in the solution.
-After the long division problem is set up, show where to start the computation procedure (find digit with the highest place value in the dividend)
-Recall and use multiplication facts correctly when doing long multiplication OR long division
-When doing long multiplication OR long division, recall place value concepts and give place value labels for digits in whole and decimal numbers,
-Follow the proper order of steps in the long division procedure - *DMSBAR* *
-Repeat the long division algorithm until I get a remainder that cannot be further divided
OR
-Continue the long division procedure so I can express the remainder as a decimal or a fraction of the quotient (grade 5-6)
-Check the long division answer with "backwards" operations
-Explain what the answer means in the story in my own words
-Think-aloud and write the steps of long division
-Think aloud and explain the answer and parts of the answer in a story problem to someone else
-Make connections between fractions, decimals and long division
-Keep my scratch work neat (so that I don't get lost)
- Teach a friend how to do long division

Non-Cognitive Indicators
-Look at my mistakes without being scared or feeling sad, so that I can fix them and get better in math
-Complete the procedure without giving up even when it gets hard or boring
-Cheer myself on after each step I get correct

 Students may use a mnemonic device to facilitate recall—Divide (Dad), Multiply (Mom), Subtract (Sister), Bring Down (Brother), Again (Aunt), Remainder (Repeat?): DMSBAR

Box 5.5 *Multiple Choice Item. Standard Format*

Targeted learning outcome/indicator:
The student/examinee will identify correct definitions of statistical terms *(Recall/ basic understanding of concepts, principles, rules).*

Directions: Select the best answer from the choices given.

1.   The difference between the highest and lowest score in a data distribution is called:
    a.   Frequency
    b.   Mean
    c.   Range
    d.   Standard Deviation

Note: Correct answer in bold.

Box 5.6 *Multiple Choice Item: Analogy Format*

Targeted learning outcome/indicator:
The student/examinee will identify correct definitions of statistical terms *(Recall/ understanding of basic concepts).*

Directions: Select the best answer from the choices given.

1.   Mean is to *Central Tendency* as Standard Deviation is to:
    a.   Frequency
    b.   Mode
    c.   Normality
    d.   Skewness
    e.   Variability

Note: Correct answer in bold.

Box 5.7 *Scenario-dependent Mutiple Choice Items*

Targeted outcome/indicator: Given published data tables, the examinee/physician will appraise and interpret statistical evidence on risk, relative risk, relative risk reduction, absolute risk reduction, odds, and odds ratios. (*Higher order thinking/problem solving*)

Directions: Examine the table below, showing results of a randomized trial of endoscopic sclerotherapy compared with endoscopic ligation for bleeding esophageal varices with respect to 1 year mortality levels. Calculate and interpret the <u>relative risk reduction</u> of ligation as compared to sclerotherapy based on the data. Select the best answers from options given.

	Death in 1 year	Alive in 1 year	Total
Ligation	18	46	64
Sclerotherapy	29	36	65

Source: *JAMA User's Guide* (2003), p. 352 – 362. Table 2B 2-4.

1. The calculated one year mortality risk in the sclerotherapy group is:
   a) 29/65-18/64 or 17%
   b) 18/64 or 28%
   c) 29/65 or 45%
   d) 36/65 or 55%

2. Relative risk reduction of ligation would be:
   a) Risk in sclerotherapy group compared to (divided by) risk in ligation group
   b) Risk in sclerotherapy group minus the risk in the ligation group
   c) The difference in risks between the 2 groups compared to the risk in the ligation group
   d) **The difference in risk between the 2 groups compared to the risk in the sclerotherapy group**

3. Based on this data set, is the following statement true? *The number of patients who would need to be switched from endoscopic sclerotherapy to endoscopic ligation to save one life during the ensuing year could be as few as 6.*
   a) **True**
   b) False
   c) Cannot be determined with information given

Box 5.8 *True False Items. Standard Format*

Targeted learning outcome/indicator:

The student/examinee will identify correct definitions of statistical terms *(Recall/ basic understanding of concepts, principles, rules).*

Directions: Indicate in the space provided to the left of each item whether the following statements are True or False.

(Answer: *false)* __ 1. The difference between the highest and lowest score in a distribution is called the frequency.

(Answer: *true)* __ 2. The score value that is found at the midpoint of a distribution of data is the median.

(Answer: *true)* __ 3. The score in a distribution with the highest frequency is called the mode.

Note: Correct answer in parenthesis

Box 5.9 *Matching Items. Standard Format*

Targeted learning outcome/indicator:

The student/examinee will identify correct definitions of statistical terms *(Recall/ basic understanding of concepts, principles, rules).*

Directions: Match the **Statistical Terms** in Column B with the **Definitions** in Column A, by filling in the blank next to the item in Column A. . Each letter response can be used only once.

Column A   **Column B**

____ 1. The difference between the highest and lowest score   a. Frequency
in a data distribution.
____ 2. The most frequent score in a data distribution.   b. Mean
____3.The sum of the scores divided by the sample size   c. Median
____ 4. The positive square root of the variance   d. Mode
____ 5. The score in a distribution that is the   e. Normal Distribution
50th percentile
____ 6. The point in a score distribution below which   f. Percentile
25% of the scores fall.   g. Quartile
                                                                                                       h. Range
                                                                                                       i. Standard deviation

Box 5.10 *Matching Items. Standard Format*

Targeted learning outcome/indicator:

The student/examinee will identify correct functions with different parts of a plant *(Recall/ basic understanding of concepts, principles, rules).*

Directions: Match the **Functions** in Column B with the **Parts of a seed-bearing, green plant** in Column A, by filling in the blank next to the item in Column A. Each letter response can be used <u>only once or not at all</u>.

Column A-Parts   **Column B-Functions**

____ 1. Carries water and food from the soil to other   a. Flower
parts of the plant.
____ 2. Anchors the plant to the ground   b. Fruit
____ 3.Grows into an adult plant   c. Leaf
____ 4. Manufactures food using sunlight   d. Seed
____ 5. Protects the seed   e. Stamen
____ 6. Attracts insects to help pollination   f. Stem
                                .   g. Roots
                                         h. Pollen

Box 5.11 *Completion Items. Various Formats*

Targeted learning outcomes/indicators

The student/examinee will:
- identify correct definitions of statistical terms *(Recall/ basic understanding of concepts, principles, rules).*
- calculate and interpret descriptive statistics for a data set provided *(Application).*

Directions: Complete the following statements by filling in the missing blanks. Some items will require calculations based on data provided. Show your work clearly on an attached sheet before you fill in the blanks.

1. The difference between the highest and lowest score in a distribution is called the ___ (Answer: *range)*
2. The score value that is found at the mid-point of a distribution of data is the ___ (Answer: *median)*
3. What is the score in a distribution with the highest frequency called? ___. (Answer: *mode)*

4. See sections a-c and the data set below. The following score distribution was obtained from a classroom test taken by 15 students:

   10, 12, 12, 17, 18, 19, 19, 19, 20, 21, 22, 23, 24, 24, 25.

   a. What is the calculated **mean** of the distribution? Answer: ___ Formula used: _____

   b. Calculate the **standard deviation**. Answer: ___ Formula used: _____

   c. Calculate and interpret the **standard score** (**z score**) for a raw score of **17** in the distribution.

   Answer: _____ Formula used: _____

   How did the student with a score of 17 perform compared to the class? (1-2 sentences):

   _____

Note: See Table 4.3 in Chapter 4 for definitions of cognitive levels in italics

Box 5.12
A context-dependent exercise using a variant of True-False item format

Karen lost her library book on the way to school. She wanted to put a notice on the bulletin board so that the other students in school could help her find it. Which of the following sentences say something that would help students find the book? See 1-7.

Circle **Yes** if it would help OR **No** if it would not. Explain your choices in the space provided below.

Yes

1. The book has a hard cover.

No

Yes

2. She lost it on a very warm day.

No

Yes

3. The English teacher asked students to read the

No   book.

Yes

4. The book title is: A Christmas Carol.

No

Yes

5. The book's cover is red.

No

Yes

6. The book is interesting..

No

Yes

7. She stopped at Marie's house on the way to

    school.

No

Explanation: [Space provided]

Table 5.1

Domain in Long Division for grade 3-5 students

Culminating, General Outcome*:*

1.0 [The student] Solves real world problems using long division with one or two digit divisors, and explains solutions (*Higher Order Thinking*)

Embedded Indicators:

1.1 Reframe long division problem in own words *(Concept Recall and Understanding)*
1.2 Identify/define math vocabulary relevant to a long division problem *(Concept Recall and Understanding)*
1.3 Apply the long division procedure in the proper sequence *(Complex Procedural Skills)*
    1.3.1 Recall the order of operations [DMSBRA - divide, multiply, subtract, bring down remainder, again (repeat)] *(Application)*
    1.3.2 Recite long division algorithm with suitable mnemonic (e.g., dad, mom, sister, brother, aunt) *(Concept Recall and Understanding)*
    1.3.3 Use multiplication facts correctly during procedure *(Application)*
    1.3.4 Apply subtraction correctly during procedure *(Application)*
    1.3.5 Apply divisibility rules to improve fluency of procedure *(Application)*
    1.3.6 Use place value concepts correctly with quotients and part quotients *(Application)*
        1.3.6.1   Use place holder in appropriate places during solution
        1.3.6.1   Correctly place digits of partial quotient and products during long division
        1.3.6.2   Self-correct incorrect placements
        1.3.6.3   Continue algorithm until a decimal remainder is reached
        1.3.6.4   Place decimal point to distinguish decimal remainder from the rest of the whole number quotient
        1.3.6.5   Interpret remainders, partial quotients correctly during/following solution
        1.3.6.6   Interpret remainders in decimal forms
        1.3.6.7   Organize and show work clearly for each step
    1.3.7   Given a real life problem, set up the divisor and dividend, label what they stand for and follow long division procedure to find solution. *(Higher Order Thinking)*
    1.3.8   Explain the quotient and any remainder of solution in a real world problem *(Higher Order Thinking)*
  1.4   Evaluate correctness of solutions to long division *(Higher Order Thinking)*
    1.5.1   Identify errors or misapplications of steps *(Application)*
    1.5.2   Self-correct errors during process *(Application)*
    1.5.3   Check answers using inverse operations (by multiplying divisor with quotient and adding remainder, as applicable) *(Application)*

Note: See Table 4.3 in Chapter 4 for definitions of cognitive levels in italics

Table 5.2
Evaluating the quality of item-writing: Structured -Response items

A. General Criteria

- Does the item match the content, conditions, and taxonomic level specified in the targeted outcomes/indicators?
- Is the item clearly written at a reading level suitable for the specified population?
- Are directions clear? If negative words are used in the directions or prompt, are these highlighted? Are double negatives avoided to prevent confusions and ambiguity?
- Is there only <u>one</u> concept or idea tested in each question? Are "double-" or "triple-barreled" items removed?
- Does the item have only <u>one</u> best or correct answer?
- Are there any clues in the items (such as, grammatical clues, clang associations, predictable response patterns, or others)?
- Does the item reflect inflammatory biases? Is there any language, graphics, or material that could offend or undermine a particular group or subgroup?
- Might there be an opportunity-to-learn bias inherent in the item that would disadvantage a group or subgroup?

B. What makes a good multiple choice item?

- Is the verbal load in the stem?
- Are the distracters plausible? Do they reflect common errors or misunderstandings of typical examinees?
- Are response options to an item of about equal difficulty?
- Are the responses parallel in form, language and content?
- Are responses about equal in length?
- Are "All of the above" or "None of the above" used sparingly and with judgment?
- Does the correct answer position vary in a list of items?
- Are responses to items listed in some logical order?
- Are response options listed vertically?

Table 5.3 Contd.

Evaluating the quality of item-writing: Structured -Response items

C. What makes a good true-false item?

- Does the propositional statement focus on one important idea, principle or concept in the domain?
- Is the proposition indisputably true or false? If verification of an opinion is being tested, is the source identified?
- Does the item avoid trivia testing or "common sense" material?
- Are verbatim excerpts from textbooks or common resources avoided?
- Are T/F items listed in some logical and consistent order?
- Are predictable patterns of correct responses avoided in item sets, like TFTFTF?
- Are true and false statements of approximately equal length?
- Are there approximately equal numbers of true or false answers on a test?
- Are "specific determiners" avoided, such as, "always", "generally", or "never"?

D. What makes a good matching exercise?

- Is the set of items homogeneous in terms of content?
- Are the premises or prompts (in Column A) longer than the response options provided (in Column B)?
- Are there more response options than there are prompts? Are the distracters plausible?
- Are responses listed in some logical order, such as, alphabetically?
- Does the list of items fall within the ideal range of 5-15?
- Does the complete exercise fit on one page?
- Do directions indicate whether the answer options can be used only once or more than once?

Table 5.3 Contd.
Evaluating the quality of item-writing: Structured -Response items

E. What makes a good completion item?

- Are the items presented in question form, or as incomplete statements that pose the question clearly?
- Are blanks used to test key concepts or main ideas?
- Are verbatim excerpts of language or text from readings avoided in items?
- Do individual items have single blanks? If there are multiple blanks in an item, are they appropriate for the content tested and used with judgment?
- Is the blank placed towards the end of an incomplete statement, or after the question mark to enhance readability? If the targeted skill requires an earlier placement of the blank, is it located appropriately?
- Are the blanks for words or phrases that are of approximately equal length?

F. What makes a good context-dependent exercise?

- Is the contextual material likely to be new to examinees?
- Does the contextual material fit the targeted developmental or age level of examinees?
- Is the contextual material clear, uncluttered and easy to read?
- Do items target higher levels of thinking?
- Are all items tied to the contextual material?
- Are the questions and contextual material balanced in terms of space usage?
- Is the length of the exercise suitable for the population?

Table 5.3
Evaluating the quality of item-writing: Constructed -Response and Essay tasks

A. General Criteria

- Does the task match the content, conditions, and taxonomic levels specified in the targeted outcomes/indicators?
- Is the item clearly written at a reading level suitable for the specified population?
- Are directions clear? If negative words are used in the directions or prompt, are these highlighted? Are double negatives avoided to prevent confusions and ambiguity?
- Does the item reflect inflammatory biases? Is there any language, graphics, or material that could offend or undermine a particular group or subgroup?
- Might there be an opportunity-to-learn bias inherent in the item that would disadvantage a group or subgroup?

B. What makes a good constructed response or essay item?

- Is the task thought provoking? Does it foster deeper thinking?
- Does the task tap into sets of connected outcomes/indicators that cannot be measured by other assessment methods or item formats?
- Does the prompt clearly delimit the task for typical examinees?
- Are there clear parameters for responses expected, such as, length, scope, and criteria for acceptability?
- Will the task parameters help prevent bluffing? (Essays)
- Is the number of tasks adequate to add reliability to the score (Short answer)?
- Are the scoring rubrics designed to minimize unreliable scoring??
- Are scoring rubrics designed to match the specified domain indicators, inferential needs, and assessment purposes?
- Are anchor papers and list of typical errors provided as a reference to scorers?
- Are the tasks and rubrics easy to use?
- Are the assessment conditions (e.g., time, space, materials) adequate for examinees to produce their best work?

Table 5.4

A *Table of Specifications for designing a paper and pencil test, showing percent weights to be allocated to different sub-domains and cognitive levels.*

Content dimensions/topics→	Therapy	Diagnosis	Prognosis	(Assessing) Harm	Total Questions (%)
Weights Allocated to Sub-domains→ **Cognitive Levels↓**	**(30%)**	**(30%)**	**(20%)**	**(20%)**	**100**
"Ask" Skills-*Concept knowledge and understanding*	3	3	2	2	10 (10%)
"Ask" Skills- *Application*	5	5	5	5	20 (20%)
"Acquire" skills- *Application*	5	5	5	5	20 (20%)
"Appraise" skills- *Higher Order Thinking*	10	10	7	8	35 (35%)
"Apply" skills *Complex procedural skills*	5	5	2	3	15 (15%)