



## Developing a Large-Scale Cognitively Diagnostic Assessment to Identify Learning Needs in Mathematics

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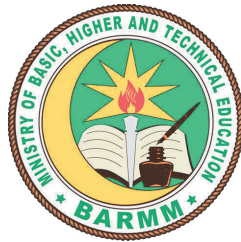


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# Acknowledgment

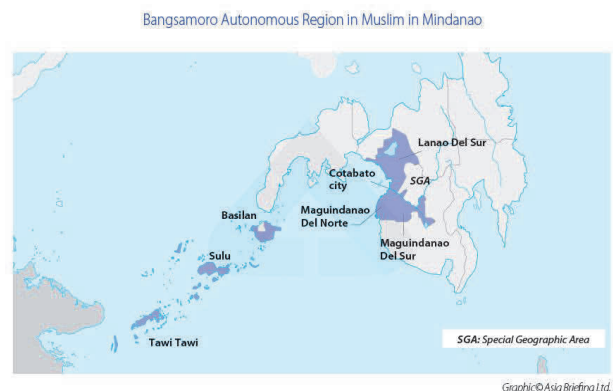
This study was conducted with support from the **Ministry of Basic, Higher and Technical Education (MBHTE)** of the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) and the **University of the Philippines Ugnayan ng Pahinungód / Oblation Corps**.



## Overview of the Test Development Process

The objectives of this assessment were to determine the academic performance of Grade 6 learners

- (a) to identify their learning needs
- (b) to inform the in-service training of teachers in BARMM.



This study involved the collection of achievement data from sampled schools in eleven (11) school divisions in BARMM.

## Overview of the Test Development Process

To address these needs, the Assessment, Curriculum and Technology Research Centre (ACTRC) suggested to design the summative assessments under the **cognitive diagnosis modeling framework**.

In this manner, these summative assessments can provide two useful information aside from the usual sum-scores:

- Students' **mastery\* or non-mastery** of the attributes/skills at the individual, classroom, and school level
- **Proficiency\* level** of the students with respect to the grade level standards

\*Note: The terms *proficient* and *mastery* are **not** related to the Philippine Department of Education's own operational definitions of these terms for its national assessment mean percentage scores.

## Cognitively Diagnostic Assessments

**Cognitively diagnostic assessments** (CDAs) are fundamentally diagnostic and when used in conjunction with **cognitive diagnosis models** (CDMs) can provide diagnostic information in the form of examinee classification with respect to **a set of skills or attributes**.

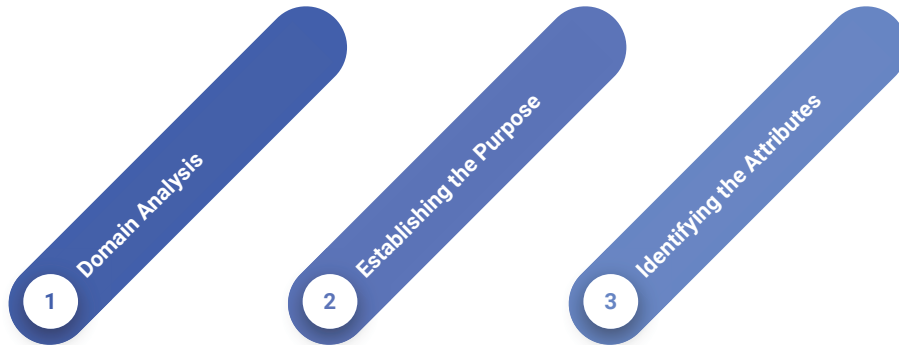
**Skills** or **attributes** can be *fine-grained* or *quite broad* depending on the context of the assessments.

In this case, a **skill** or an **attribute** is defined as **set of learning competencies** that should be mastered\* by the Grade 6 learners to be deemed proficient\* in a learning area.

\*Note: The terms *proficient* and *mastery* are **not** related to the Philippine Department of Education's own operational definitions of these terms for its national assessment mean percentage scores.

# Attribute Identification

For an assessment to be cognitively diagnostic, it needs to be designed to measure **various components required** of someone deemed **proficient\*** in a particular domain of interest.



\*Note: The term *proficient* is **not** related to the Philippine Department of Education's own operational definition of this term for its national assessment mean percentage scores.

## Domain Analysis

Review the competencies listed in the **Most Essential Learning Competencies (MELCs)** in Mathematics based on the Philippine Department of Education curriculum guide.

What are the **skills/attributes** necessary for a Grade 6 learner to master\* to be deemed **proficient\*** in Mathematics?

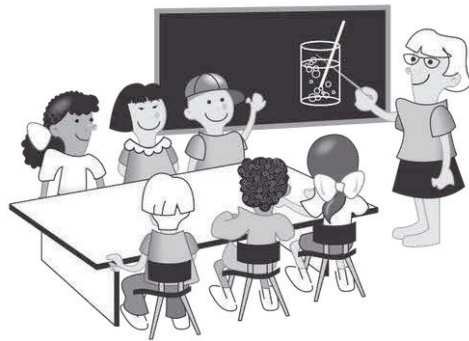


\*Note: The terms *proficient* and *mastery* are **not** related to the Philippine Department of Education's own operational definitions of these terms for its national assessment mean percentage scores.

## Establishing the Purpose

To develop **summative assessments** that will provide feedback that can be useful in designing MBHTE's

- **In-Service Education and Training (INSET)** for their teachers; and
- **Remediation programs** for their Grade 6 learners



## Identifying the Attributes

List down the (very important) specific skills/attributes first based on MELCs in Mathematics and then examine whether some of them can be combined to come up with **broader (but still useful) skills/attributes**.

Are these attributes **measurable**? Is it possible to write items to measure these attributes?

If not, consider **revising the list of attributes** until these attributes are all measurable.

# Identified Attributes for Grade 6 Math

## **Number and Number Sense**

A1 = Represents, compares and orders fractions, decimals, percent and integers.

A2 = Performs the four basic operations in fractions, decimals and integers following the GEMDAS rule.

A3 = Interprets exponents, ratio, proportion, and percentage in various meanings.

A4 = Solves problems (routine/non-routine) involving numbers (integers, fractions and decimals), ratio, proportion, percent and percentage in different contexts.

## **Geometry**

B1 = Describes properties of different 2-dimensional (polygons and circles) and solid/space (cube, prism, pyramid, cylinder, cone, sphere) figures.

# Identified Attributes for Grade 6 Math

## **Measurement**

C1 = Solves problems involving speed and average rate, time, distance, area of composite figures (triangle, rectangle, square, circle, semi-circle), surface areas and volume of solid/space figures.

## **Patterns and Algebra**

D1 = Formulates the rule to find the nth term of a sequence.

D2 = Translates verbal phrases into mathematical expressions/ equations and vice versa.

## **Statistics and Probability**

E1 = Interprets and analyzes data presented in tables, bar and line graphs, pictographs and pie charts.

E2 = Solves problems (routine and non-routine) involving theoretical and experimental probability.

## Instructions to Item Writers

1. Create **single-attribute items** for each attribute on the list, including the prerequisite skills.
2. Write **two-, three-, or four-attribute (or more) items** for any *logical* combination of attributes.

There might be cases when novel type of items needs to be created.

3. The **total number of items measuring each attribute in the Q-matrix (i.e., test specification) should comparable** (not necessarily equal but still close to each other).

## Q-matrix (Tatsuoka, 1984) in Math

Item	A1	A2	A3	A4	B1	C1	D1	D2	E1	E2
1	1	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0
3	1	0	0	0	0	0	0	0	0	0
4	1	0	0	0	0	0	0	0	0	0
5	0	1	0	0	0	0	0	0	0	0
6	1	1	0	0	0	0	0	0	0	0
7	0	1	0	0	0	0	0	0	0	0
8	0	1	0	0	0	0	0	0	0	0
9	0	1	0	0	0	0	0	0	0	0
10	0	0	1	0	0	0	0	0	0	0
11	0	0	1	0	0	0	0	0	0	0
12	0	1	1	0	0	0	0	0	0	0
13	0	1	0	1	0	0	0	0	0	0
14	0	1	1	1	0	0	0	0	0	0
15	0	1	1	1	0	0	0	0	0	0

The Q-matrix specifies the attributes needed by an examinee to successfully answer each item.

## Data Analysis

The Math assessment was administered to a total of **6,398 Grade 6 learners** across the 11 school divisions of BARMM.

CDM analysis was implemented using the **higher order generalized deterministic inputs, noisy, “and” gate** (G-DINA; de la Torre, 2011) **model** to generate more diagnostic information (i.e., **examinee mastery profiles**) from the Math assessment data.

$$f[P(\boldsymbol{\alpha}_{ij}^*)] = \delta_{j0} + \sum_{k=1}^{K_j^*} \delta_{jk} \alpha_{lk} + \sum_{k'=k+1}^{K_j^*} \sum_{k=1}^{K_j^*-1} \delta_{jkk'} \alpha_{lk} \alpha_{lk'} + \cdots + \delta_{j12\dots K_j^*} \prod_{k=1}^{K_j^*} \alpha_{lk}$$

## Data Analysis

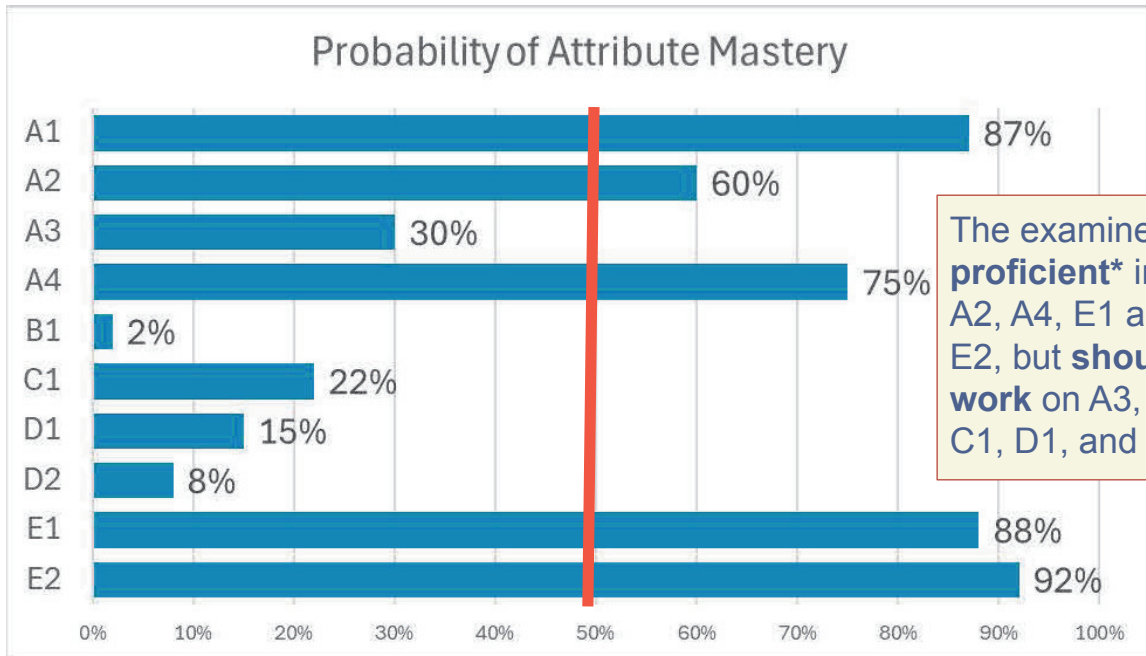
**Empirical Q-matrix validation** (de la Torre & Chiu, 2016) was also performed to identify possible misspecification of attributes in the test items.

Results were consulted with the **subject matter experts** if any modifications in the Q-matrix were necessary.

The **classification accuracy indices** (reliability measure) for each attribute in Math was computed and found to be acceptable (i.e., all are at least 0.70).

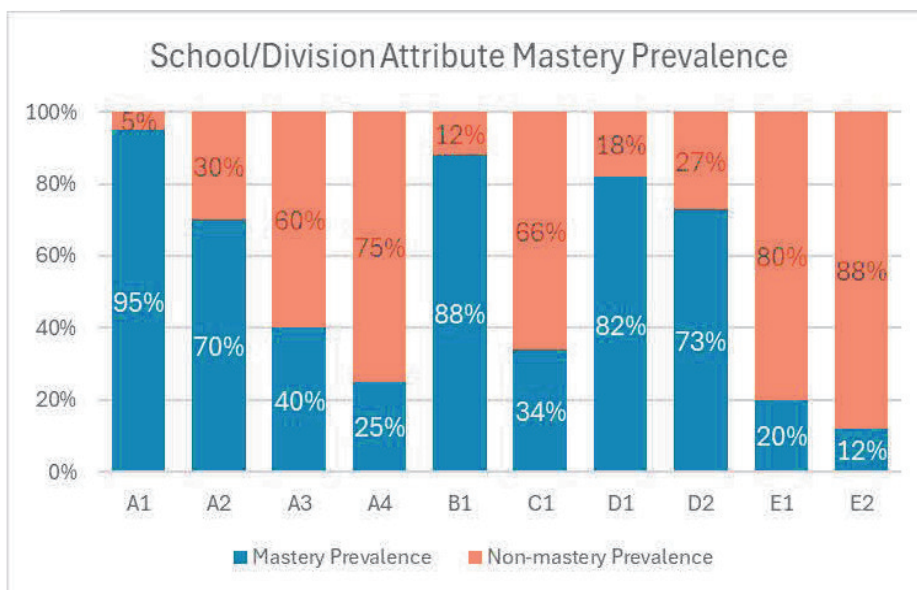


## Sample Grade 6 Examinee Profile in Math



\*Note: The term *proficient* is **not** related to the Philippine Department of Education's own operational definition of this term for its national assessment mean percentage scores.

## Sample School/Division Profile in Math



Majority of the Grade 6 learners **mastered\*** A1, A2, B1, D1, and D2.

However, majority of them **should work** on A3, A4, C1, E1 and E2.

**Mastery prevalence** refers to the percentage of examinees that have the mastery\* of a specific attribute.

\*Note: The term *mastery* is **not** related to the Philippine Department of Education's own operational definition of this term for its national assessments.

## Utilization of CDM results

CDM-generated reports can be produced at the

- Regional Level
- Division Level (each division can have its own training design for teachers)
- School Level (school administrators can craft action plans for their own teacher training)
- Classroom Level (teachers can design targeted interventions)
- Individual Level (students can learn their strengths and weaknesses)

Policies and intervention programs can be tailor-fitted to the division, school, classroom or even individual level.

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