Do Your Learners Do the Thinking?

DEVELOPING LEARNERS'

HIGHER-ORDER THINKING SKILLS

IN MATHEMATICS FOR GRADES 7, 8, 9 & 10

MENTOR'S GUIDE

A Professional Learning Package on the
PPST Indicators 1.5.2 and 1.5.3

This Mentor's Guide in Mathematics for Grades 7, 8, 9 & 10 was developed through the **Philippine National Research Center for Teacher Quality (RCTQ)**, a partnership between the **Philippine Normal University** and the **SiMERR National Research Centre–University of New England,** with support from the **Australian Government**.

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INTRODUCTION TO THE MENTOR'S GUIDE

Hello, dear Mentor! Welcome to this
Professional Learning Package in Mathematics!

This *Mentor's Guide* was developed to complement the *Teacher's Resource*. This has been created from the item bank and *Teacher's Resource* on PPST indicators 1.5.2 and 1.5.3.

This is intended for you – master teachers and school leaders – to coach and further support our teachers effectively and, at the same time, collaborate with them. Collaboration among teachers and school mentors are essential to enhance the teaching and learning process. This 'team-up' approach suggested in this resource aims to help build better communication and interactions among staff as you learn from each other.

As a highly proficient practitioner, you have an important role to play in the achievement of the intended learning outcomes stipulated in the materials. Likewise, your participation in this endeavor will help assist mentees acquire the skills, knowledge, attitude, and values as they advance their career level.

Note: **The Teacher's Resource in Mathematics, includes 24 assessment items involving 93 individual questions.**

Both the *Teacher's Resource* and this *Mentor's Guide* are appropriate for use in Learning Action Cells (LAC), classroom applications, and mentoring, among others, as complementary materials.

Mentoring Instructions

To assist you in the role, you may refer to these mentoring instructions:

Read the teacher's resource. It is important to read the item bank and teacher's resource to understand the background upon which the material is built, and know learn the main pointers teachers can acquire while preparing their teaching plan and dealing with their student learners.

Set a one-on-one session. This session is simply a chance for teachers to deal with what they have learned by sharing their thoughts and having constructive and complementary discussions with another person.

Ideas for Mentors:

Using the items in LACs might include:

- Initially, selecting a single Item/or Item set to use to introduce the structure and features of the package to mentees
- Suggesting as small set of items around a single topic for mentees to try before a next LAC session, so the whole group can feedback and share ideas on the same set of items
- Discussing the full range of HOTS strategies being modelled in the resource
- Asking mentees to identify an item of interest to review, try with their students, evaluate and then report back to their group
- Leading your LACs group to identify some general strategies that support HOTS, e.g., *building questions up in a topic from unistructural to multistructural to relational*; or *using open questions and scaffolds*.

Ideas for Mentees:

Using the items:

- Trying some items themselves to reflect on their knowledge and understanding
- Trying some item with their students – maybe some in early grades and some in higher grades
- Sharing some items with their school colleagues – this could be useful for collaborative discussions; clarifying the focus the school has on the Philippine Curriculum that they are currently implementing
- Adapting or developing some items for your school's context.

Further or complementary study:

- Reading more about HOTS
- Exploring PISA competencies and PISA testing and how they might be used in your school

How to use the Mentor's Guide?

This *Mentor's Guide* provides an outline of how you may support your teachers. The following are provided in this material:

Capacitating my Mentee on the SOLO-based Assessment Items

Provides activities and/or outlines a work plan for the master teachers, school heads, and supervisors to coach and mentor teachers about the identified strategies in the *Teacher's Resource.*

Reflection Log

Provides opportunities for the master teachers, school heads, and supervisors to assist teachers in reflecting on their teaching strategy, the **S**tructure of the **O**bserved **L**earning **O**utcome (SOLO) model, the challenges they encountered, and how they addressed the challenges that arose.

As a mentor, you need to make sure that the teachers who are using the *Teacher's Resource* have an understanding of its purpose and the content provided in the Philippine Professional Standards for Teachers (PPST) **Domain 1: Content Knowledge and Pedagogy** (Strand 1.5).

This is also a chance for you to undertake the following:

- Clarify important points indicated in the key learnings and the guide below.
- Provide feedback based on how teachers answered the items or activities.
- Ask for and confirm changes in teacher perspectives and teaching plans.
- Initiate and conduct individual and group discussions you think are necessary and relevant.

Capacitating my mentee on the

SOLO-based Assessment

Activity 1. Organizing LAC Session

Introduction

The content of the *Teacher's Resource* can be used to engage teachers in collaborative learning sessions such as the Learning Action Cell (LAC). Both mentors and teachers should be given the chance to share insights and expertise in teaching higher-order thinking skills to learners. Similarly, it is vital that teachers share the challenges encountered during the teaching-learning process so that, with guidance and support, these challenges can start to be addressed.

Being able to master the **S**tructure of the **O**bserved **L**earning **O**utcome (SOLO) model requires reading, discussion and practice. While the ideas may sound straightforward, both you and your colleagues (mentees) require hands-on activities to help comprehend the model.

It is interesting that as you spend more time on SOLO, new brain-based perspectives associated with teaching and learning open up. In the following mentoring activities, you will begin applying the SOLO model to current pen and paper questions. These can serve as diagnostic, formative or summative activities employed in classrooms.

An important characteristic of the SOLO Model is a series of levels that measures increasing sophistication (quality) in responses to questions directed to learned tasks. There are five levels of response in the Basic SOLO Model, but three are most relevant to the work undertaken

The reader is encouraged to read and analyse the work provided in the following, Activity 2, for a much fuller appreciation of Basic SOLO and the SOLO levels. However, as an initial introduction the three levels used to classify responses are referred to as unistructural, multistructural and relational where:

A **unistructural** response involves one relevant operation or action from the stimulus;

A **multistructural** response involves several relevant independent operations or actions;

A **relational** response integrates all relevant pieces of information and operations from the stimulus.

These three levels comprise a U-M-R **cycle** of development, and offer an important pedagogical tool for teachers to assist them in planning instruction and assessment.

Getting Started First Time

An introduction to the HOTS Teacher's Resource

First in conversation with the teachers choose a question from a subject area in Mathematics from the Teacher Resource. Teachers might suggest a preferred question to start.

Teachers may wish to start with an item from Mathematics and Grade 7. They may wish to choose Item 001.

Now talk through the first page (see a copy below). This information situates the item in the Philippine Curriculum as expected taught content and also the related PISA competency. It also describes briefly the HOTS thinking strategy employed in the question.

Item No. 001	Subject	Mathematics – Geometry
	Grade Level	7
	Topic	Angles of Polygons (part 1)
	PISA Competency	Relates to the understanding of spatial and geometric phenomena and relationships.
	K to 12 Curriculum Competency	M7GE-IIIf-1: The learner derives inductively the relationship of exterior and interior angles of a convex polygon. **Content Standards and Performance Standard:** • *The learner* demonstrates understanding of key concepts of geometry of shapes and sizes, and geometric relationships. • *The learner* is able to create models of plane figures and formulate and solve accurately authentic problems involving sides and angles of a polygon.
	Higher Order Thinking Strategy adopted	✓ Explicitly using SOLO (from U → M → R) ✓ Alternative question taking a different approach, method, or technique ☐ Presenting information in a different form ☐ Reversing the way that a solution is traditionally achieved ☐ Providing an erroneous answer and asking students to correct mistakes ☐ Compare and contrast two similar features ☐ Other

Next move onto the questions. Most questions in this Resource have a STEM. A STEM contains information necessary to be able to undertake the question. It usually does not have a question within it.

Item 001 Grade 7 Mathematics: Weight

Question 5

Sarah joined a community outreach last Sunday. She was in-charge of packing fruits particularly ponkans before putting them in crates. Each crate weighs 3 kilograms when empty, an individual ponkan averages 0.2 kilograms. When the crate is full it weighs 12 kilograms.

This STEM sets the scene or situates the learner in the area in which the questions are to be answered.

What follows in this item are three questions (Question 5 a1, a2, and a3) based around SOLO levels. The expectation is that students will be able to respond up to a certain level and after this, the student will make mistakes or be unable to process the question adequately.

Note: all questions relate back to the STEM in some way. Also, the question difficulty (in terms of SOLO) increases as the learner proceeds through the item.

Teachers should be given the Item and the three questions. Teachers should work with a partner and discuss each question and write down what they think an appropriate correct response would be provided by a student. They may also consider what incorrect responses students might make in the different question parts.

Once all teachers, either singly or in pairs, have completed all items than teachers as a group should work their way through the answers comparing the responses they think students would make.

When this is done we will now go more formally through each question part and teachers would agree on the answer for the first part. Disagreements should be clarified.

Question 5 a1.

What is the total weight of ponkan placed in the crate?

Your Answer:

The process will now proceed to the second question part.

Question 5 a2.

How many ponkans can Sarah place in a full crate?

Your Answer:

Question 5 a3.

At another farm, the packers found that they could fit 50 ponkans in a crate with the same weight. How much did their ponkans weigh?

Your Answer:

After a fulsome discussion the Mentor should provide the formal answer. This can be found in the latter part of the resource and two aspects are particular relevant here.

SAMPLE ANSWERS

Q5 a1:

Nine (9) kilograms. 12 – 3 = 9

Q5 a2:

Let x – be the number of ponkans

Representation:

$0.2x + 3 = 12$

$0.2x = 12 - 3$

$0.2x = 9$

$x = 9/0.2$

$x = 45$ ponkans can be placed in a full crate

Q5 a3:

Let x – be the weight of a ponkan

Representation:

$50x + 3 = 12$

$50x = 9$

$x = 9/50 = 0.18$ kilograms

Finally teachers should be asked to consider the Writer's reflection about the Item.

Reflection

Question 5. Represents Stem (overall information) needed for the following three questions. Respondents will need to return to the Stem to complete all question parts.

Question 5 a1. is at the *unistructural* level as it requires **one** arithmetic operation (a subtraction involving two numbers given in the question). In addition respondents need to identify important data that are needed, and ignoring the data that are irrelevant, and having a plan/approach to solve the problem.

For **Question 5 a2.** The level is *multistructural* as the respondent is expected to undertake a number of single sequential steps to reach a solution drawing on relevant pieces of information. This differs from the first question as it only required a single step or operation. In the case of a multistructural question the steps are in a known sequential order.

For **Question 5 a3**. The answer would be at the *relational* level as the question does not follow a set of sequential steps. The question is asking respondents to reverse their train of thought from what has been asked previously. It requires a consideration (thinking) to consider all the information and then to work out what is needed. There needs to be oversight of the whole question and this needs to occur while individual steps are undertaken. In the case of a relational question the respondent must identify and maintain the connections among the constructs they presented.

The session ends with Final commentary from teachers including: What stood out for them; How do they think their students would perform (at what level) and Would they like to try this item with students in different grades and report back at the next meeting about their findings.

As a possible extension to this Activity is to offer to have teachers prepare and share an alternative or different questions at each of the levels.

Another possibility, and this is optional, is to offer teachers an Extended Abstract Question. An example of an extended abstract question for this Activity would be:

> *Which do you think would be more beneficial for the business-owners? To have a crate with more ponkans packed, or to have less but heavier ones?*

Once again, allow teachers in groups to analyze the question and talk about responses.

> **Acceptable answer:** *It will depend on the pattern of consumers' purchasing. Would they go for quantity, i.e., the number of fruits? Or would consumers want bigger ones, but less in number?*
>
> There is no clear cut answer to the question. It may have an answer but that will depend on some caveat, qualifying comment or a condition placed on the question. In this case, the extended abstract level, the respondent is well aware of the range of approaches and possibilities and includes these alternatives in the response. Like the relational question, learners can link and explain several ideas related to the topic. But this time, they can also consider alternatives and their impact. These alternatives are not necessarily mentioned or implied in the text.

HANDS-ON ACTIVITY
Overtime and after teachers have had experience with a number of Activities and Questions, and tried some with their students, you will help your mentees in formulating questions using the SOLO model. 1. As a mentor, provide a learning competency to your mentee(s). 2. Let them prepare questions on the unistructural, multistructural, relational, in particular. (Note: extended abstract level questions are optional). 3. Review the questions they formulated. Provide comments and suggestions on how your mentee(s) can improve the questions they formulated. 4. If you are mentoring two or more teachers, it is a good idea to have a peer review of outputs. 5. Give them time to revise their outputs before the final review of the questions.

Activity 2. Introduction to the Basic SOLO Model

Enclosed is a summary of the Basic SOLO Model. Teachers have access to this in the Teacher's Resource in Mathematics. It is reproduced below. This will help guide your thinking as well as establish baseline information for you and your teacher colleagues. It is worth stressing that there is more to the SOLO model but this is designed to be an entry into SOLO-type thinking, especially as it is related to ideas about learning quality – in particular, a practical classroom based operational thinking related to lower-order and higher-order thinking.

This Introduction, in four Parts, to the basic SOLO Model was written by Professor John Pegg of the SiMERR National Research Centre in Australia. The aim is to situate the reader within the early, and still highly relevant, research and thinking that has been undertaken on SOLO so as to provide a stronger base for the reader in assessing learner responses. This is particularly relevant in the case of explaining lower-order and higher-order thinking.

Part 1 Background to SOLO

The SOLO Model (the SOLO Taxonomy) of John Biggs and Kevin Collis (Biggs & Collis 1982, 1991; Pegg 2003, 2020) is a cognitive (brain-based) developmental framework that offers a useful tool to explore the quality of a learner response in a specific context. The notion of 'quality' is not unfamiliar in Education discussions, its importance is seldom challenged. However, trying to tie down a meaning for quality and what it means operationally has shown not to be so easy.

At its basis, SOLO is interested in describing the nature of a learner response to a question or stimulus. This information offers insights into what a learner knows, understands and can do, as well as directions along which instruction may most profitably proceed.

When asked the 'quality' of a student's learning, a common response is to mention the number of facts or pieces of relevant information a person knows something about. This information might be further supported by citing scores on a recent examination, or the number of correct items a person has achieved in some test/quiz.

Such descriptions of 'quality', definitely offer a perspective on learning performance – a view that knowledge creation is about acquiring more and more pieces of information. In terms of operationalizing 'quality', this description can result in predictable and routine approaches to instruction involving drill and practice. However, this view can also limit a breadth of practices in teaching involving more demanding higher-order practices such as analysis, explanation, and synthesis, and that may lead to unfortunate long-term consequences for a learner.

Being told that a student obtained a score of 73% on a test tells us very little about the quality of the learning, except that the student probably knows more than someone who achieved 63% on the same test and not as much as someone who scored 83%. However, little can be interpreted if the comparison was with a person who achieved 70-72% OR 74-75%.

Data are clear that tests are often limited in their ability to discriminate meaningful student learning on scores within a few percentage points of one another. The impact of misguided interpretations of learning is even more dramatic when scores hover around the 50% mark. A mark which usually holds an unprecedented and undeserved importance by society.

Also, there are often issues interpreting student scores when students obtain the same score. Do similar scores on a test mean that students have the same questions correct or incorrect? Ideas of equivalence can be misleading. It is possible, for example, that one student earned their marks on the most straightforward questions across the test, while another respondent might be able to achieve correct responses on some quite difficult questions in certain areas and perform poorly in other areas.

It would seem quite likely that a student who is able to respond to some more difficult questions is likely to be able to advance more quickly with support, than a student who is only able to undertake the more basic questions correctly.

Further, and more importantly, numeric descriptions of quality do little to explain:

- what a learner knows or understands;
- in what directions a teacher, or the learner themselves, might move to improve or advance their learning; and, as importantly,
- how might this notion of 'quality' link to how the brain learns.

SOLO offers help in addressing these concerns. The focus of the SOLO categorization is on cognitive processes in addressing an issue or question rather than the end-products alone. SOLO offers a framework that enables explorations and descriptions of the quality of *'how well'* learning has progressed in different contexts. This provides a genuine balance to more typical approaches, mentioned earlier, that describe 'how much' is known.

The application of SOLO to the analysis of learner responses enables insights into learner cognitive development as well as understandings of possible cognitive blockages associated with the pattern of ideas that are impacting on leaner growth. As such, SOLO offers teachers insights into learner thinking and subsequent teaching actions.

Part 2 Overview of SOLO

Over the past 40 plus years, since the late 1970s, SOLO has built a substantial evidence base involving many thousands of research studies resulting in many hundreds of published articles. Now, SOLO has an extensive and growing universal following.

SOLO has emerged out as a consequence of describing learning through the eyes of a learner involving two separate but related activities. This involves:

- the acquisition or development of relevant ideas, facts, skills, concepts, processes and strategies; and
- the use of this acquired information in some form such as to solve problems, apply understanding, or explain or interpret meaning.

This reflects the two main ideas in Part 1 above concerning describing quality as 'how much' and 'how well'.

In terms of this current publication, this dual approach to thinking about 'quality' linked to SOLO, offers a realistic and practical description of what lower-order and higher-order thinking looks like as demonstrated in a learner's response.

In particular, SOLO enables teachers to distinguish between skills, knowledge and content that may be considered as lower-order functioning (or the result of surface learning) and those described as higher-order functioning (or the result of deep learning). SOLO supports teachers with ways to identify the practical meaning of lower-order and higher-order quality, and ways to identify examples in different contexts.

Such practical advice on applying decision skills, to distinguish lower- and higher-order functioning is achieved by describing an operationalized balance between:

(i) the degree of complexity of how responses are structured by the brain; and
(ii) relevant information associated with the content/context.

As lower-order skills and understandings are necessary pre-requisites for higher-order thinking, the ability of teachers to efficiently and effectively separate lower- and higher-order categorizations is a critically important skill. SOLO offers a structure upon which such decisions can be made.

This significant strength of the SOLO model lies in its links with neuroscience and how the brain learns, i.e., the cognitive (brain) processes. These brain-based ideas behind SOLO are linked to:

- information processing capacity, such as, working memory demands;
- the creation of neural pathways/networks through deliberate practice;
- the amount of information able to be retained by the learner in a particular domain; and,
- features specific to learning tasks or activities.

Overall, despite the obvious importance of the notion of 'quality' to education, descriptions of what is meant by quality have not received the attention, or use in practice, it deserves. SOLO offers an alternative to traditional assessment counts of 'how many', by placing SOLO center stage in learning and teaching. Teachers who learn to apply SOLO routinely in the classroom find that it is relevant and useful to understanding learning situations in all subject areas.

Further, when used correctly, SOLO can help teachers not only apply more *objective* and *systematic* assessment techniques, but it can help clarify developmental learning pathways to inform lesson and syllabus development, as well as strengthen formative-assessment approaches.

There are four main aspects to modern descriptions of SOLO. These are:

- SOLO levels
- the SOLO modes
- SOLO levels within modes
- SOLO cycles.

All four aspects are important for completeness, but initially, it is sufficient for the reader to become familiar with the meaning, use and application of the concepts around **SOLO levels (Section Part 3 below).** This feature is the one most prominent in early general discussions. Also, when information about SOLO is provided, say on the Web, the information provided on **SOLO levels** is usually the sole focus.

Part 3 Introduction to *SOLO Levels: Language and Meaning*

Biggs and Collis (1982) believe the way the brain structures learnt material, 'structural organization' of knowledge, is the difference between well learned from poorly learned material. It is this structural aspect of knowledge in the brain that underpins descriptions of quality. They (Biggs and Collis):

> believe that there are 'natural' stages in the growth of learning any complex material or skill… in certain important aspects these stages are similar to, but not identical with, the developmental stages in thinking described by Piaget and his co-workers. (Biggs & Collis, 1982, p. 15)

SOLO Levels

SOLO Levels are the most well-known aspect of the SOLO model. The SOLO levels describe the increasing sophistication (the increasing quality) of responses in handling certain tasks/questions relevant to a particular activity or domain. The levels are given specific names that every teacher needs to acquire and use accurately and consistently.

In the 1982 version of SOLO there are five levels of response. They represent a developmental continuum beginning from a level that describes an irrelevant or incorrect understanding, through a series of three levels describing how the brain structures understanding to an acceptable degree, to a fifth and final level where a response extends beyond what might typically be expected as an acceptable response.

Unistructural, Multistructural and Relational Levels

In what follows the middle three levels are described first, and the first and last of the five levels are considered second. The three middle levels have the names unistructural, multistructural and relational. The names are almost self-explanatory. Their level descriptions are:

A *unistructural* (U) response is one where the focus is on a single attribute. It might involve writing a single sentence with one main idea, or undertaking one algorithm, or providing one reason or suggestion, or identifying one relevant piece of information from the stimulus, etc. The key to this level is in the name. The prefix 'uni' stands for 'oneness'. So, the 'structure' of the response is a single aspect that is relevant to the question or activity.

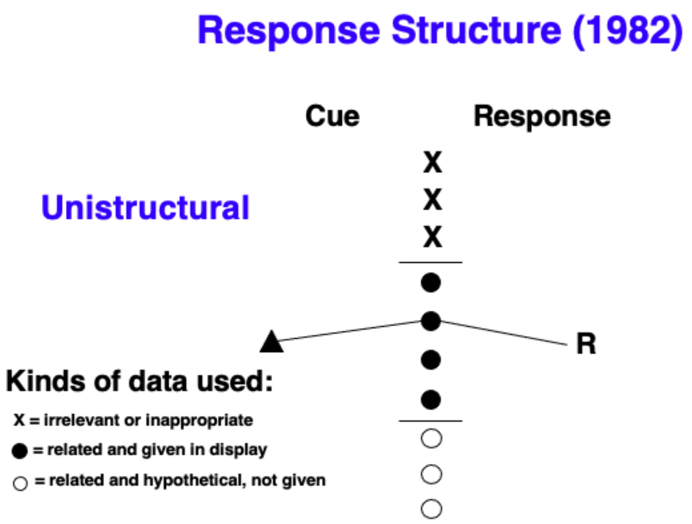


Figure 1: Unistructural level

A *multistructural* (M) response is one that includes several relevant independent pieces of information from the stimulus or comprises a number (i.e., more than 1) usually sequential actions, explanations, algorithms, etc. The key to this level is in the name. The prefix 'multi' stands for 'many'. So, the structure of the response contains more than one aspect that is relevant to the question or activity. Further the different aspects are seen to be independent of one another. There is no integration of pieces of information or seeing inter-related aspects.

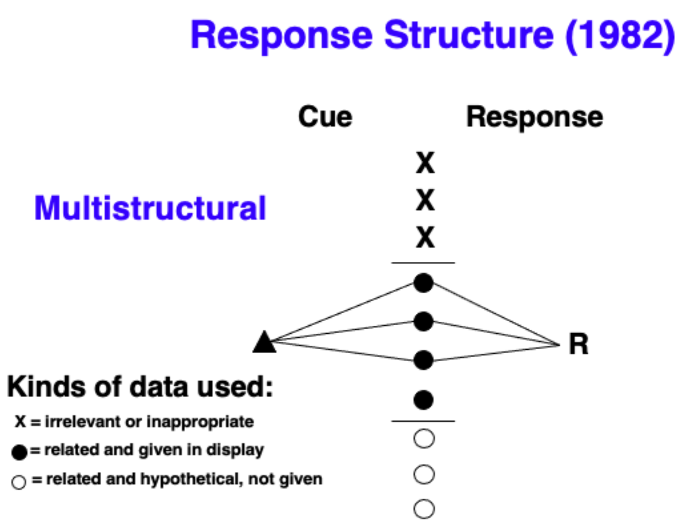


Figure 2: the Multistructural level

A *relational* (R) response is one that integrates all relevant pieces of information or data from the stimulus. These aspects in the stimulus are now linked to one another resulting in an overall coherence, a pattern, to the data presented and any approach to be undertaken. There is no inconsistency within the known system.

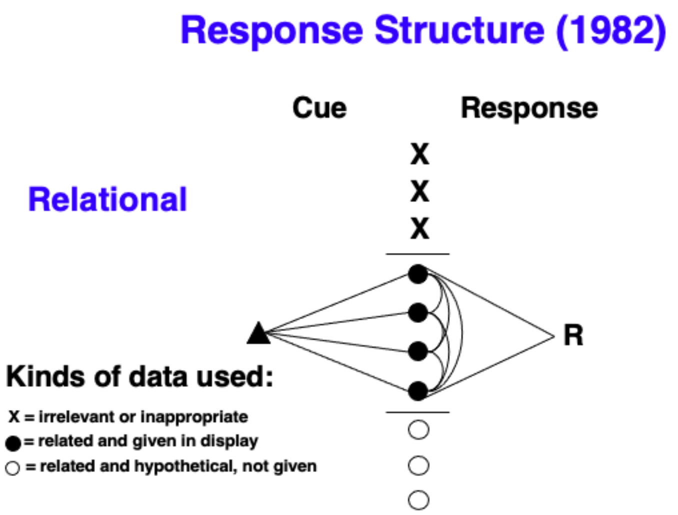
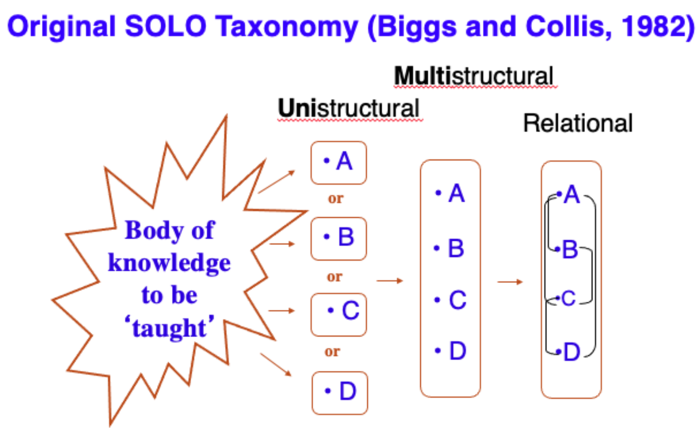


Figure 3: The Relational level

These three levels are often referred to as a SOLO unistructural–multistructural–relational cycle or a SOLO UMR cycle.



The three levels described above offer descriptions of increasing complex structures of thinking by the brain in which higher levels are directly built upon preceding levels, i.e., the multistructural response contains the unistructural response, a relational response identifies the relationships among the separate elements of the multistructural response. Taken together, the three levels represent a SOLO UMR cycle.

Prestructural and Extended Abstract levels

Two other SOLO levels can be found in the literature. They are most relevant to and used when people talk about the SOLO Taxonomy based around the 1982 book. The names of the two levels are prestructural and extended abstract.

The prestructural level, as the word indicates, occurs 'pre' or 'before' the structure starts and so it is used to code responses that fail to address a relevant feature. Such a response is described as:

A prestructural level (Pre) of response is one that does not focus on the relevant question or activity. Usually, the answer is quickly given with little thought. The answer is likely to be irrelevant or simply repeat information already provided in the question or activity.

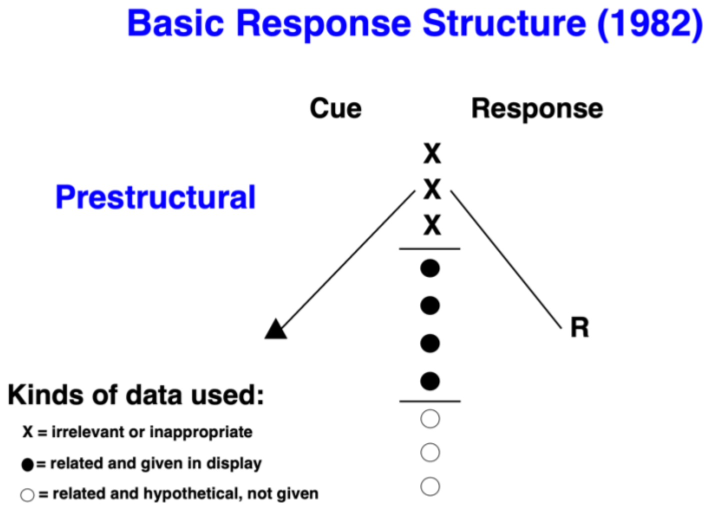


Figure 4: The Prestructural level

The extended abstract level, as the word meaning indicates, occurs after a relational response. So, it is used to identify a response that goes beyond what might typically be expected. In such cases the answer would have a deeper perhaps more abstract feel, hence, the name.

An *extended abstract* (EA) response is one that goes beyond what was expected at the relational level. In school situations it can involve deduction, ability to close on situations not experienced. Answers can be held open or qualified to allow for logical alternatives.

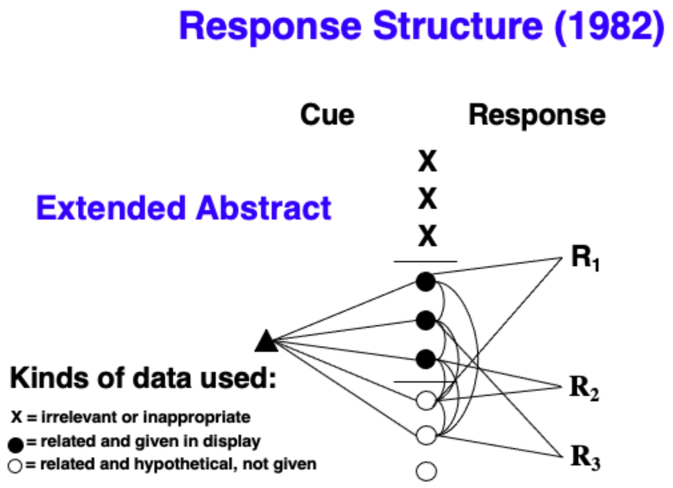


Figure 5: The Extended Abstract level

The two outer levels, one below and one above the middle three levels, respectively, are named prestructural and extended abstract.

Finally, a useful question is: What are the variables that determine or underpin the level of response given by a learner? There are five.

The Degree of Abstractness: The first level (pre-structural) is personal to the learner and not the topic. The next three levels (unistructural, multistructural and relational) are relevant to the area of focus and share similar characteristics. The last level (extended abstract) is more general and extends beyond the previous levels in an appropriate abstract way.

Number of Organizing Dimensions: The first level does not have an organizing dimension relevant to the activity or question. For the next three levels the organization is based on one dimension, several independent dimensions, and an integration of the independent dimension. The final level moves beyond the previous by adding an overarching general framework encompassing the earlier work.

Consistency: The first level is the most inconsistent. This encompasses the information provided and the response provided. The next two levels provide growing consistency as more elements are used in determining a response. The relational level response is consistent within the internal or provided context of the learner. The extended abstract level response not only is able to work within the internal context but can also consider external principles or other contexts providing a much deeper and often more nuanced response.

Openness of Conclusion: The list of levels demonstrates a graduation of thinking from 'closed' to 'open'. 'Closed' is where learners respond very quickly to an activity or stimulus, sometimes without even understanding the question. As a learner offers increasing levels of response, there is more time and consideration provided, i.e., the response becomes more 'open' so as to enable more room for considered interpretations. This 'openness' is maximized for extended abstract responses.

Sequence of Levels: The levels are developmental with an earlier level being a building block for the next level. A unistructural response is within the related multistructural response. A relational response integrates the elements of the earlier multistructural response. An extended abstract response has within it the relational response but extends it through embedding the response within a broader external environment or through incorporating broader principles or theoretical positions.

Part 4 The SOLO Model and Instruction

The strength of the SOLO model is the linking of the hierarchical nature of cognitive development through the modes (not mentioned in this Summary) and the cyclical nature of learning through the levels.

In terms of SOLO levels, each level provides building blocks for the next higher level. SOLO also provides teachers with a common and shared language that enables them to describe in a meaningful way their observations of student performance. This is particularly important when teachers try to articulate differences between lower-order and higher-order skills and understandings.

Emerging from careful research work of SOLO is the observation that while the lower levels in the SOLO model can be taught in the traditional sense. The shift to developing learner higher-order skills and for them to be able to respond to questions with higher-order responses requires a quality in the thinking of the learner that cannot be guaranteed by explicit teaching alone.

There appears to be certain teaching approaches and strategies that might be better applied when students are identified as responding at one SOLO level than when at another. Knowledge of this pattern can better help teachers develop a rationale for their actions and help inform the nature of their instruction to targeted groups.

Part 5 Final Comment

Overall, it has been clear that for the great majority of teachers, assessment of subjects taught in school are dominated by a focus on content (in the form of facts) and skills (associated with computational techniques), and the ability of learners to reproduce these on demand. This narrow focus can have a sterile effect upon innovations and developments in the Mathematics curriculum and even on what it means for a person to think mathematically or scientifically.

The issue here for teachers is about

(i) interpreting the quality of the learning in terms of 'how well' material is understood (Biggs & Collis, 1982; 1991); and

(ii) selecting the most appropriate strategies, procedures or teaching activities for their students at their SOLO response level.

Higher-order goals of learning, such as judgement formation, solving relevant problems, and on developing understanding, must encompass not only the content, but also the interrelationships between various processes and procedures.

Nevertheless, these more demanding skills and developments must be built on fundamental lower-order knowledge, skills and understandings. Quality education, instruction and learner outcomes, must embrace the full range of abilities as described and categorized through the SOLO model in the topics identified.

Activity 3 Lac Session on Background to HOTS in the Classroom

LAC Objectives: At the end of this 1.5-hour LAC session, teachers would be able to:

a. summarize the PISA 2018 results of Filipino learners;
b. define higher-order thinking skills (HOTS);
c. identify which strand in the PPST promotes HOTS; and
d. appreciate how the assessment items in the teacher's resource can help promote higher-order thinking skills.

BEFORE THE SESSION
✓ Inform teachers about the schedule, topic, and objectives of the session and ask them to read the Executive Summary of https://www.deped.gov.ph/wp-content/uploads/2019/12/PISA-2018-Philippine-National-Report.pdf;
✓ Confirm who will serve as the documenter, preferably on a rotating basis;
✓ Prepare the venue and necessary equipment, such as a laptop and/or projector (if face to face);
✓ Ensure that the seating arrangement during the LAC session complies with physical distancing protocols (if face to face). Alternatively, an agreed platform can be set up if the session will be conducted online. Make sure that the selected platform is accessible to all LAC members;
✓ If the LAC session is online, make sure to share guidelines for conducting online meetings (e.g., find a quiet place in your home where you can focus, mute your mic when not speaking, etc.). Prepare slides needed for the session.

DURING THE SESSION

1. **Pulse check (10 minutes)**
    - **8 minutes:** Start the LAC session with the following check-in questions: *What is something that worries you about your students as learners? How do you deal with that worry?*
    - **2 minutes:** Check/summarize if there are common worries and common ways of dealing with them.

2. **Introduction of topic (5 minutes)**
    - Ask teachers who among them have read the Executive Summary of *PISA 2018: National Report of the Philippines*. If most of them have read the Executive Summary, ask them to pair up and share with each other how they felt while reading the Executive Summary. If only a few have read it, ask them to pair up and quickly go over the summary together.

3. **Activity (65 minutes)**
    - **5 minutes:** Given what they read, ask the teachers to reflect: *Since the PISA does not assess how well learners remember facts but how they are able to interpret texts, solve mathematics problems, or explain phenomena scientifically using their knowledge and reasoning skills (higher-order thinking skills (HOTS)), how do we define HOTS as teachers? Given our HOTS definition/s, what do we need to do as teachers to help our learners develop their HOTS?*
    - After teachers reflect on their own views, show these definitions from the *PPST Resource Package Module 3* (on the board, manila paper or on a slide):
        - CREATIVE THINKING SKILLS: These are thinking skills that involve exploring ideas, generating possibilities and looking for many right answers rather than just one.
        - CRITICAL THINKING SKILLS: These are high level thinking skills such as analysis, evaluation, interpretation, or synthesis of information and application of creative thought to form an argument, solve a problem, or reach a conclusion.
        - HIGHER-ORDER THINKING SKILLS: These are complex thinking processes which include analysis, evaluation, synthesis, reflection and creativity.
    - **25 minutes:** Ask the teachers to discuss the following in groups of 4 to 5: *Are the definitions of creative thinking skills, critical thinking skills, and HOTS from the PPST Resource Package similar to their own definitions? What are the similarities and difference? Given the HOTS definition/s, what do we need to do as teachers to help our learners develop their HOTS?*

- **10 minutes:** Ask a representative from each group to share the highlights of the group discussion. Limit each sharing to a few minutes.
- **5 minutes:** Summarize the group sharing. Connect comments to PPST Strand 1.5 (*Strategies for developing critical and creative thinking, as well as other higher-order thinking skills*) and on what teachers need to do to develop learners' HOTS. Emphasize that teachers need to apply a range of strategies for developing HOTS not just to improve PISA scores but also to ensure that learners are able to "build a reliable compass and the navigation tools to find their own way through an increasingly volatile, uncertain and ambiguous world" (Schleicher, 2019). By developing learners' HOTS, we help learners think for themselves and collaborate with others meaningfully, in work and citizenship.
- **5 minutes:** Introduce the *Teacher's Resource* by saying that the resource "is designed to set up instructional support for you to assist the effective implementation of teaching strategies in helping learners develop higher-order thinking skills through the PPST Strand 1.5" by providing items or activities that can be used as examples when explaining/reviewing a concept or as test items.
- **5 minutes:** Distribute the *Teacher's Resource* and ask the teachers to go through the first three items for the grade level they are teaching.
- **5 minutes:** Ask the teachers about their impressions of the items. Tell them, "Don't mind the terms unistructural, multistructural, and relational for now. We will discuss that in another LAC session."
- **5 minutes:** Ask the teachers whether they think the items can help develop learners' HOTS and why they think so/don't think so.
- Mention that in the next LAC session, teachers will consider more items and be introduced to how the items are structured and what "unistructural, multistructural, and relational" mean. As homework, please read the Introductory pages of the *Teacher's Resource*.
- Close the session by thanking the teachers for their contributions and active participation. Say that you hope to have that same level of enthusiasm in the next LAC session.

AFTER THE SESSION

✓ Remind teachers to read Introductory pages of the *Teacher's Resource* (from the cover to *What teachers can expect from this Resource Material*) a few days before the second LAC session.

✓ Remind teachers of the schedule (and modality) of the next LAC session and give them the necessary details should the session be online.

Activity 4. Preparing SOLO-based Questions

Critical Thinking and Problem-Solving based Approaches

Figure 1 depicts Mathematical Literacy as the relationship between mathematical reasoning and the problem solving (mathematical modelling) cycle according to PISA 2021 Mathematics Framework. It can also be noted that the Twin Goals of Mathematics (Figure 2) set by the Department of Education has also been reflected in the 2021 PISA Mathematics Framework. This twin goals of mathematics in the K to 12 basic education levels emphasizes Critical Thinking and Problem-Solving as its core.

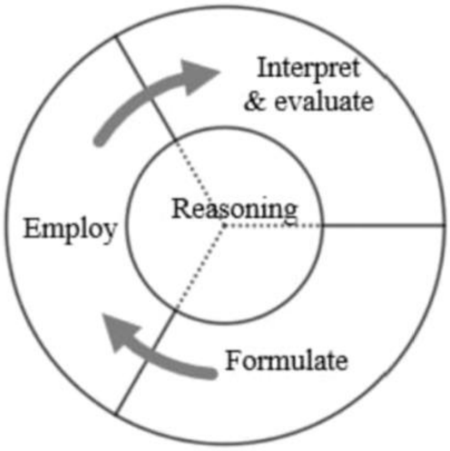


Figure 1. Mathematical Literacy (2021 PISA Mathematics Framework, 2018)

The first goal in Figure 2 is Critical thinking, according to Scriven and Paul (1987), it is the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action. On the other hand, according to Polya, mathematical problem solving is finding a way around a difficulty, around an obstacle, and finding a solution to a problem that is unknown.

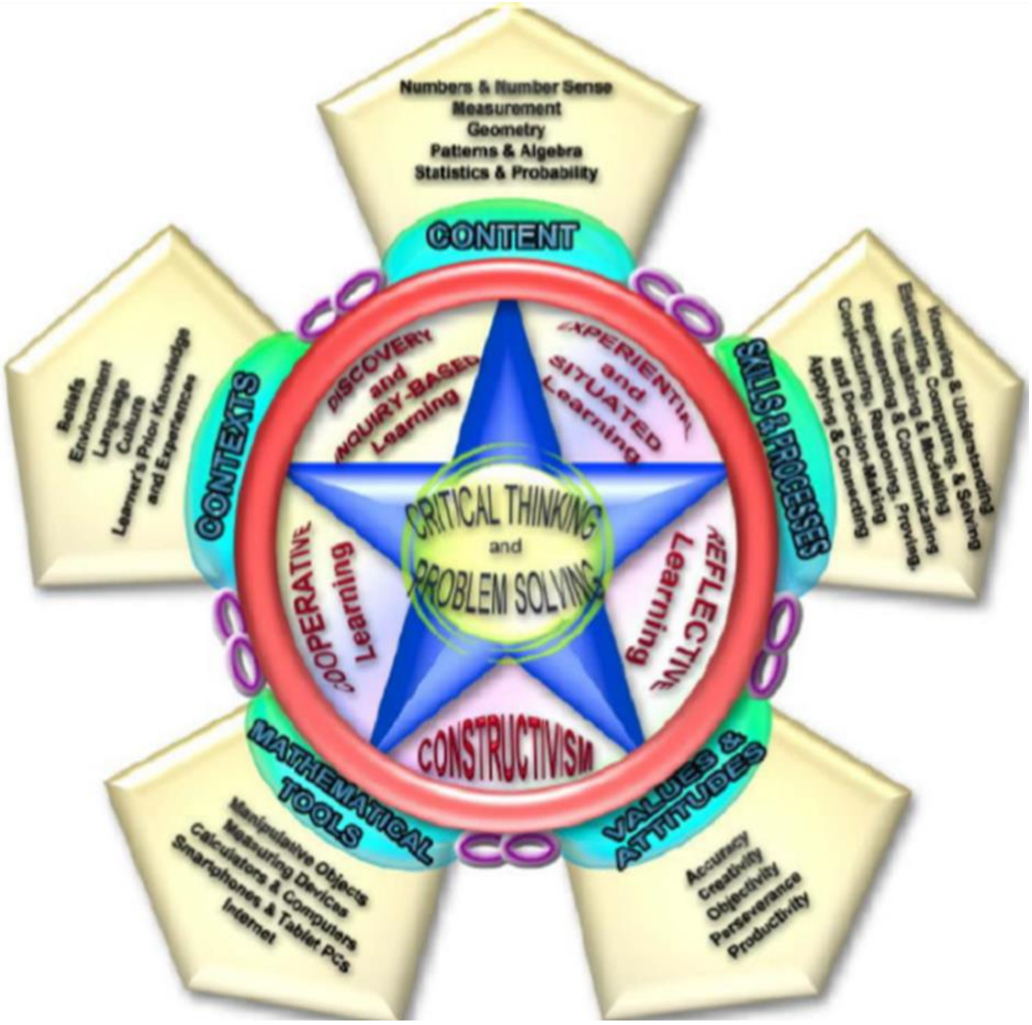


Figure 2. K to 12 Mathematics Conceptual Framework

These two goals according to DepEd are achieved using an organized and rigorous curriculum content, a well-defined set of high-level skills and processes, desirable values and attitudes, and appropriate tools, taking into account the different contexts of Filipino learners.

In the illustrations of Practice (pedagogy and assessment practices), think of a question/problem/activity in which answers provided have mistakes/misconceptions that will use Critical Thinking and Problem-Solving based Approaches. Questions involving Critical Thinking and Problem-Solving usually starts with a Multistructural level.

Choose a specific grade level topic with corresponding PISA Competency and K to 12 Competency. Complete the table below and provide the necessary activities/questions, acceptable responses. Finally, write some remarks on how well the learners engaged in the activities using a particular SOLO level that you used in your classroom/s. What have you learned from the experience? What are some of your reflections?

Assessing Mathematical Literacy through Mathematical Reasoning & Computational Thinking

PISA 2021 offers a framework in assessing mathematical literacy in the 21st century which includes mathematical reasoning and some aspects of computational thinking. This chapter will present some problems and solving it using mathematical reasoning and computational thinking with the aid of SOLO. This assessment is aimed to present problems assessing Mathematics Literacy using mathematical reasoning and computational thinking. More specifically, it aims

1. To be able to present problems that involves Mathematical Reasoning.
2. To be able to present problems that involved Computational Thinking.
3. To be able to present these problems using SOLO Learning Approach.

Choose a specific grade level topic with corresponding PISA Competency and K to 12 Competency. Complete the table below and provide the necessary activities/questions, acceptable responses. Finally, write some remarks on how well the learners engaged in the activities using a particular SOLO level that you used in your classroom/s. What have you learned from the experience? What are some of your reflections?

Note to Mentors for Enacting Mathematical Approaches

Mathematical Enactment is teacher's enactments to mathematical practices in a classroom. Teacher enactments are teachers' actual constructions and practices inside a classroom. According to Tatto (2008), there are three hypothesized sub-domains for the framework for mathematics pedagogical content knowledge (p.4). Table 1 shows these subdomains and aspects of mathematics pedagogical content knowledge used in TEDS-M 2008.

Table 1. Subdomains and aspects of mathematics pedagogical content knowledge used in TEDS-M

Subdomains	Activities
Mathematics curricular knowledge	* Establishing appropriate learning goals * Knowing different assessment formats * Selecting possible pathways and seeing connections within the curriculum * Identifying the key ideas in learning programs * Knowledge of mathematics curriculum
Knowledge of planning for mathematics teaching and learning	* Planning or selecting appropriate activities * Choosing assessment formats * Predicting typical learner's responses, including misconceptions * Planning appropriate methods for representing mathematical ideas * Linking didactical methods and instructional designs * Identifying different approaches for solving mathematical problems * Planning mathematical lessons
Enacting mathematics for teaching and learning	* Analyzing or evaluating learners' mathematical solutions or arguments * Analyzing the content of students' questions * Diagnosing typical students' responses, including misconceptions * Explaining or representing mathematical concepts or procedures * Generating fruitful questions * Responding to unexpected mathematical issues * Providing appropriate feedback

Note: Adapted from "Conceptualizing and Measuring Mathematical Knowledge for Teaching: Issues from TEDS-M, an IEA Cross-National Study" by S.L. Senk, RR. Peck, K. Bankov and M.Tatto (2008). ICME-11. pp. 1-15.

In enacting mathematical approaches, the teacher may conceptualize a lesson that may include two (2) or more SOLO-based items from the *Teacher's Resource* in Mathematics. Moreover, lessons might take more than one (1) instructional period and may allow individual and collaborative activities. The teacher may also plan synchronous and asynchronous activities accordingly.

REFLECTION LOG

Ask your mentee to reflect on his/her experiences in adapting the SOLO. Use the following guide:

1. **How would you describe your understanding of the SOLO model?**

2. **Describe your experiences in integrating SOLO in your teaching practice? Discuss any positive experiences.**

3. **What challenges have you encountered in integrating SOLO in your practice?**

4. **How did you address those challenges?**

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