OVERVIEW OF THE EARLY MATHEMATICS ASSESSMENT SYSTEM (EMAS)

What is the EMAS?

The Early Mathematics Assessment System (EMAS) is a reliable and valid research-based assessment of early mathematical thinking that draws on modern cognitive science as well as developmental and educational research (Ginsburg & Pappas, 2016). Created by Dr. Herb Ginsburg and colleagues at Teachers College, Columbia University, and expanded and adapted by researchers at CASTL, the EMAS is designed to measure a broad range of mathematical content.

Function of the EMAS

The EMAS was designed with three purposes in mind (Ginsburg & Pappas, 2016). First, it has applications as a formative assessment, meaning that teachers can use EMAS data to provide students with differentiated, appropriate instruction tailored to their individual needs. Second, it can be used to broadly evaluate programs or assess needs across a large group of classrooms; for example, EMAS data could help identify school divisions in need of additional support around early math. Third, it can be used as a screening tool to identify students at risk for difficulties in math.

EMAS at a glance

- Teachers administer the assessment to students individually using a flip book and manipulatives.
- The assessment takes approximately 20-25 minutes per student to administer in the fall and spring.
- Items are designed to capture a wide range and variety of early math skills. Students are **not** expected to get all items correct.
- It uses hands-on materials to engage students and help teachers observe students' thinking.
- It is aligned with the Virginia Foundation Blocks (2013), Virginia Standards of Learning (2016), and Clements and Sarama's Mathematics Learning Trajectories (2009). See Appendix A.

Module 1	Module 2	Module 3	Module 4
Geometry	**Patterning**	**Numeracy**	**Computation**
• Shape Matching & Identification • Shape Properties • Composing Shapes	• Recognizing Patterns • Reproducing Patterns • Extending Patterns • Creating Patterns	• Counting and Cardinality • Subitizing • Comparing & Ordering Numbers • Composing & Decomposing Numbers • Recognizing & Writing Numerals • Describing Sets • Ordinal Numbers • Sharing Fairly	• Adding & Subtracting

What skills are assessed with the EMAS?

The EMAS is designed to focus on key foundational skills in each mathematics sub-domain that set students on a successful early math trajectory. The EMAS is comprised of the four modules indicated above. The number of items in each module varies from fall to spring, but there is a larger number of numeracy items as compared with other sub-domains because of the strong focus on this area in kindergarten.

EMAS Development over Time

When VKRP began in 2014, the original EMAS that Ginsburg and colleagues (2010) developed was used to assess students' mathematics skills at the start of kindergarten. The gradual state-wide roll-out of VKRP allowed teachers and administrators to provide feedback about the EMAS. The most commonly heard feedback was that they would like the EMAS to: 1) Be expanded down to pre-k and up to the end of kindergarten; 2) Be more sensitive to the performance of students with average or advanced skills so that teachers could better understand the needs of students across the developmental continuum; and 3) Be better-aligned to the Virginia Standards of Learning.

During the 2017-2018 school-year, the VKRP team set out to make these revisions to the EMAS. To expand the assessment, the team:

- Developed or adapted nearly 200 additional items capturing numeracy, operations, geometry, and patterning.
- Consulted with early childhood math experts, including Herb Ginsburg, the original author of the EMAS, and colleagues at the Virginia Department of Education.
- Cross-walked each item with Clements' and Sarama's (2009) learning trajectories, the Virginia Foundation Blocks early learning standards, and the 2016 Kindergarten Math Standards of Learning.
- Sought input from a nationally-recognized expert on educational measurement, Patrick Meyer.
- Pilot-tested each new item with approximately 275 children, ranging in age from 4 to 7 years old.
- Used state-of-the-art statistical methods to analyze each item, examining, for example, how students of different ages responded to each item.
- Used the statistical results to piece together our new assessments.

Psychometric Properties of the Revised VKRP EMAS

Item-response theory (IRT) is an advanced statistical approach that allows us to determine whether the range of difficulty of the items is appropriate for the students being assessed and provides an additional estimate of the measure's reliability. Researchers assessed 910 children ages 3 to 8.4 years old. Items were divided into four groups so that no child had to take all 200 items, but researchers made sure that each new item was given to at least 132 children.

After data were gathered on the new items, researchers combined this new data with data from students assessed through the 2018 kindergarten VKRP for a total sample of 35,814 children. Based on a careful analysis of each item, the research team constructed four age levels for the new EMAS: fall Pre-K, spring Pre-K, fall K, and spring K. Items were selected to represent a range of skills across the four subdomains and to target an appropriate average level of difficulty for each age level. The research team also deliberately selected some easier and some more challenging items for each level so that teachers can gauge which students need extra support and which may be exceeding grade-level expectations.

Lastly, the research team converted the new EMAS scores into growth scores so that teachers and schools can track students' math growth over time. Different EMAS tests have different items on them and different numbers of subdomain items, so raw scores cannot be compared directly across age levels. However, the scaled growth score is calculated based on the results of the IRT analyses and puts the results from each of the forms on a standard scale.

In summary, the VKRP research team undertook a careful process to develop a new and expanded set of EMAS assessments to assess students from pre-K through kindergarten and track growth over time. These new assessments show very good measurement properties, are quick to deliver, and are engaging for students.

Summary statistics of the four new EMAS forms are provided in the table below.

New Form Breakdown

Table 1. Summary Statistics of the Four New EMAS Forms

Grade and Window	Number of Items	Mean Difficulty	Range of Difficulty	Geom.	Patng.	Num.	Comp.
Fall PreK	33	-0.91	[-2.90, 0.40]	9	6	16	2
Spring PreK	35	0.25	[-1.96, 1.97]	8	4	18	5
Fall K	35	0.25	[-1.96, 2.06]	8	5	15	7
Spring K	34	1.11	[-1.01, 3.59]	9	5	15	5

Note. Geom. = Geometry, Ptng. = Patterning, Num. = Numeracy, Comp. = Computation

Appendix A: EMAS Items and SOL/Trajectory Alignment

Sample Items

Domain	Skill	Item	SOL	Trajectory
Geometry	Shape Matching and Identification	Recognize and name a rectangle	Recognize and name shapes (circle, triangle, rectangle, and square) (FB.4c) Identify and describe plane figures (circle, triangle, square, and rectangle) (K.10a)	Recognize some nontypical squares and triangles and may recognize some rectangles, but usually not rhombuses
	Shape Properties	Recognize shapes with 4 equal sides (square)	Identify representations of plane figures (circle, triangle, square, and rectangle) regardless of their positions and orientations in space (K.10c) Identify, trace, describe, and sort plane figures (triangles, squares, rectangles, and circles) according to number of sides, vertices, and angles (1.11a)	Recognize properties of shapes and recognize sides aas distinct geometric properties
	Composing Shapes	Composing a new shape out of smaller shapes ("Can you put any of these shapes together to make a square?")	N/A	Make new shapes out of smaller shapes
Patterning	Recognizing Patterns	Recognize ABAB pattern ("Here are two groups of pictures. Which one is a repeating pattern?")	Identify anad explore simple patterns, i.e., AB, AB; red, blue, red, blue (FB.6b) Identify, describe, extend, create, and transfer repeating patterns (K.13)	N/A
	Reproducing Patterns	Reproduce ABAB pattern	Identify, describe, extend, create, and transfer repeating patterns (K.13)	Duplicate simple ABAB patterns and then ABBABB patterns
	Extending Patterns	Extend ABBABB pattern	Identify, describe, extend, create, and transfer repeating patterns (K.13)	Extend more complex patterns, such as ABBABB by adding on several ABB units to the end of the pattern

Numeracy	Counting and Cardinality	One-to-one counting – 6 chips (“Please count these chips for me.”	Count a group (set/collection) of five to ten objects by touching each object as it is counted and saying the correct number (one-to-one correspondence) (FB.1b) Tell how many are in a given set of 20 or fewer objects by counting orally (K.1a)	Accurately count groups with 6 and 10 objects
	Subitizing	Subitizing – 4 dots (“How many dots did you see?”)	N/A	Instantly recognize collections up to 5
	Describing Sets	Changes in sets (“Bear had 3 red balloons. Then Duck gave him 3 yellow balloons. Does Bear have more or fewer balloons than before?”)	Describe changes in groups (sets/collections) by using more when groups of objects (sets) are combined (added together) (FB.2a) Given no more than three sets, each set containing 10 or fewer concrete objects, will compare and describe one set as having more, fewer, or the same number of objects as the other set(s) (K.2a)	N/A
	Recognizing and Writing Numerals	Write numerals to represent a quantity - 5	Read, write, and represent numbers from 0 through 20 (K.1b)	Copy and/or write numerals 0 to 9
	Composing Numbers	Show ways to make 7 (“Can you show me a different way I can make 7 by putting some chips in one pile and some chips in another pile?”)	Recognize and describe with fluency part-whole relationships for numbers up to 10 (K.4b) Recognize and describe with fluency part-whole relationships for numbers up to 10 (1.7a)	Solve addition and part-part-whole problems by direct modeling, counting all, and using objects; Understand some basic part-whole concepts; Can sometimes start unknown problems by trial and error
Computation	Addition	Adding with objects (“Bear has 3 cookies. His mom gives him 1 more. How many cookies does Bear have altogether?”)	Model and solve single-step story and picture problems with sums to 10 and differences within 10, using concrete objects (K.6)	Add and subtract small numbers (up to 3+2) using objects
	Subtraction	Subtraction with ten frame (“Here are three cookies. If you take one away, how many cookies would you have left?”)	Model and solve single-step story and picture problems with sums to 10 and differences within 10, using concrete objects (K.6)	Add and subtract small numbers (up to 3+2) using objects

References

Clements, D. H., & Sarama, J. (2009). *Learning and teaching early math: The learning trajectories approach*. New York: Routledge.

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Ginsburg, H. P., Pappas, S., & Lee, Y. (2010). Early Mathematics Assessment System. An unpublished assessment measure created as part of the NIH supported project Computer Guided Comprehensive Mathematics Assessment for Young Children (Project number 1 RO1 HD051538-01).

Lee, Y. (2016). Psychometric analyses of the Birthday Party. ZDM Mathematics Education, 48, 961–975.

Additional Publications

Ertle, B., Rosenfeld, D., Presser, A. L., & Goldstein, M. (2016). Preparing preschool teachers to use and benefit from formative assessment: The Birthday Party Assessment professional development system. *ZDM Mathematics Education, 48*, 977-989.

Ginsberg, H. P. (2016). Helping early childhood educators to understand and assess young children's mathematical minds. *ZDM Mathematics Education, 48*, 941-946.