VKRP
Virginia Kindergarten Readiness Program

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. Created by Dr. Herb Ginsburg and colleagues at Teachers College, Columbia University, [1] and expanded and adapted by researchers at CASTL, the EMAS is designed to measure a broad range of mathematical content in pre-kindergarten and kindergarten.

Function of the EMAS

There are three main goals of the EMAS. First, it is a useful tool for describing entry level math skills at the beginning of the school year. Second, it is designed to capture fall-to-spring growth within an academic year and across time. Third, it can be used to identifying strengths and areas of growth for individual students, and in aggregate, EMAS data can be used to assess needs across a large group of classrooms; for example, EMAS data could help identify school divisions in need of additional support around early mathematics.

EMAS at a glance

- Teachers have the option of administering the In-person or the Remote EMAS to students.
- Teachers administer the assessment to students individually, using a flip book (in-person) and manipulatives.
- The assessment takes approximately 20-25 minutes per student to administer.
- Items are designed to capture a wide range and variety of early math skills.
- It uses hands-on materials to engage students and to help teachers observe students' thinking.
- It is aligned with Virginia's Early Learning and Development Standards (ELDS; 2021), Virginia Standards of Learning (SOL; 2016), and Clements and Sarama's Mathematics Learning Trajectories (2009)[2].
- It is given in the fall and spring of pre-kindergarten and kindergarten.

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 and in pre-k and kindergarten, but there is a larger number of numeracy items as compared with other sub-domains because of the strong focus on this area in early childhood.

Module 1	Module 2	Module 3	Module 4
Geometry	Patterning	Numeracy	Computation
• Shape Recognition • Shape Matching • Shape Properties • Composing Shapes	• Imitating patterns • Recognizing patterns • Reproducing Patterns • Extending Patterns • Creating Patterns	• Recognizing quantities • Counting and Cardinality • Subitizing • Comparing and Ordering Numbers • Composing and Decomposing Numbers • Numerals	• Addition • Subtraction

[1] 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).

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

EMAS Development over Time

Pre-K and K Expansion

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.

From 2017-2021, the VKRP team set out to make these revisions to the EMAS. To expand the assessment, the team:

- Developed or adapted 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, the Virginia Early Learning and Development Standards and the 2016 Kindergarten Math Standards of Learning.
- Sought input from a nationally recognized experts on educational measurement.
- Pilot-tested each new item.
- 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 a vertically aligned EMAS that spans from the fall of pre-k (three-year-old) to the end of kindergarten.

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.

After data were gathered on the new items, researchers combined this new data with data from students assessed with the EMAS. Based on a careful analysis of each item, the research team constructed six EMAS forms: fall Pre-K 3, spring Pre-K 3, fall Pre-K 4, spring Pre-K 4, 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 need additional challenge.

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.

EMAS Form Breakdown

Table 1
Summary Statistics of the Pre-K 3, Pre-K 4 and K EMAS Forms

Grade and Window	Number of Items	Internal Reliability (Cronbach's Alpha)
Fall Pre-K 3	28	0.912
Spring Pre-K 3	32	0.927
Fall Pre-K 4	33	0.923
Spring Pre-K 4	35	0.917
Fall K	35	0.918
Spring K	34	0.909

Appendix A: EMAS Items and ELDS/SOL/Trajectory Alignment

Sample Items

Domain	Skill	Item	ELDS/SOL	Trajectory
Geometry	Shape Recognition	Recognize and name a rectangle	Correctly names squares, rectangles, and triangles regardless of size or orientation (CD3.3t) 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)	Describes attributes of two- and three-dimensional shapes (e.g., "A square has four corners/angles", "a triangle has three straight sides") (CD3.3u) Identify and describe plane figures (circle, triangle, square, and rectangle) (K.10a) 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 as distinct geometric properties
	Composing Shapes	Composing a new shape out of smaller shapes (square)	Uses smaller shapes to compose larger and different shapes (e.g., two triangles make one square) (CD3.3s)	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?")	Shows understanding of simple patterns by recognizing and extending simple, repeating, "ABAB" patterns (e.g., of movements such as "tap head, tap knees, tap head..."; or of objects such	N/A

			as "red car, yellow car, red car...") (CD3.4j)	
	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)	Shows accuracy in demonstrating one- to-one correspondence for up to 10 objects (CD3.1s) 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?")	Instantly recognizes a collection of up to 10 objects (i.e., subitizes) (CD3.1w)	Instantly recognize collections up to 5
	Describing Sets	Changes in sets (more)	Compares sets of objects that range in size from 1-5, as having "more" or "fewer" (CD3.1p) Compares sets of objects that range in size from 1-10, as having "more", "fewer" or "same" (CD3.1z)	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?")	Solves addition (joining) problems using manipulatives (e.g., fingers, objects, tally marks) (CD3.2c) 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?")	Solves subtraction (separating) problems using manipulatives (e.g., fingers, objects, tally marks) (CD3.2d) 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

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