

TASK

Teacher Analysis of Student Knowledge:
A Measure of Learning Trajectory-Oriented
Formative Assessment



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This interactive electronic report provides an overview of an innovative new instrument developed by researchers at the Consortium for Policy Research in Education (CPRE) to authentically measure teachers' formative assessment practices in mathematics. The **Teacher Analysis of Student Knowledge**, or TASK, instrument assesses mathematics teachers' knowledge of formative assessment and learning trajectories, important components of the instructional knowledge necessary to teach to the high expectations of the Common Core State Standards (CCSS).

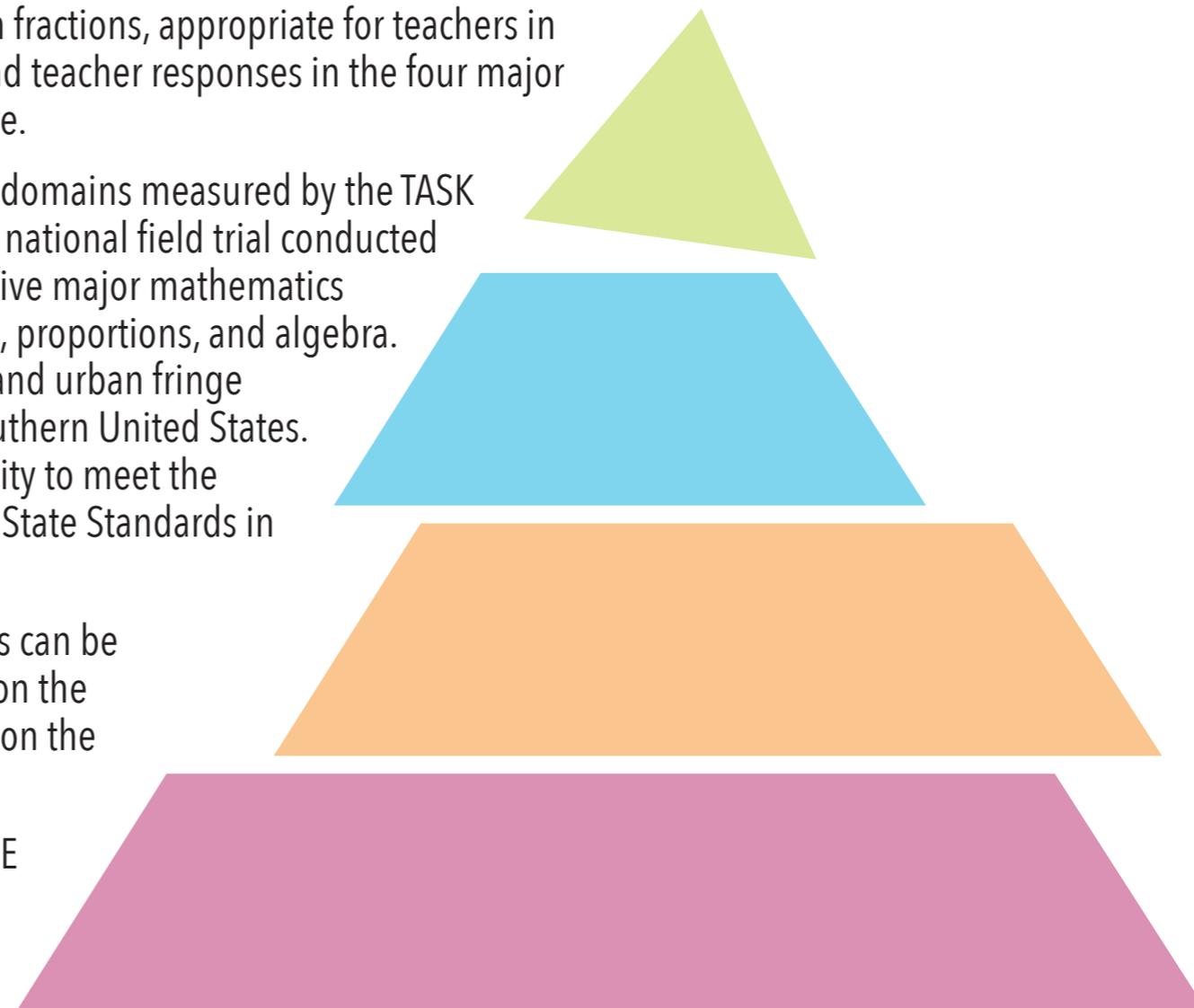
The electronic report has three main sections. The first section gives an overview of the TASK instrument, the theory behind the instrument, our approach to scoring the results, and the ways in which the instrument can be used by educators and researchers.

The second section provides a sample TASK in fractions, appropriate for teachers in grades 3-5. This section includes the items and teacher responses in the four major domains that the TASK is designed to measure.

The third section provides an overview of the domains measured by the TASK instrument and reports the results of a major national field trial conducted by CPRE of 1,261 teachers in grades K-10 in five major mathematics content areas: addition, subtraction, fractions, proportions, and algebra. These results were collected from five urban and urban fringe districts in five states in the northeast and southern United States. They provide a sense of current teacher capacity to meet the ambitious expectations of the Common Core State Standards in Mathematics.

Each of these sections and its subcomponents can be accessed either through the triangular icons on the **home page** or through the table of contents on the left.

This work was generously supported by the GE Foundation.



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A **Teacher Analysis of Student Knowledge**, or TASK, is a grade-specific, online assessment for mathematics teachers which measures important components of the instructional knowledge necessary to teach to the high expectations of the Common Core State Standards in Mathematics.

TASKs focus on the application of pedagogical content knowledge to specific student situations. They are carefully designed to measure teachers' emphases on procedural and conceptual understanding, and their recognition of the learning trajectories underlying core mathematics content areas. They require teachers to recognize different levels of student understanding represented in students' work, and to explain student response strategies in relation to research-based learning trajectories. TASKs are authentic representations of teacher understanding because they ask teachers to respond in their own words, not select from multiple-choice options.

The TASK instrument measures four domains in relation to formative assessment:

1. Teachers' knowledge of mathematical concepts
2. Teachers' analysis of student understanding
3. Teachers' knowledge of mathematical learning trajectories
4. Teachers' instructional decision making

TASKs have been developed for five mathematics content areas:

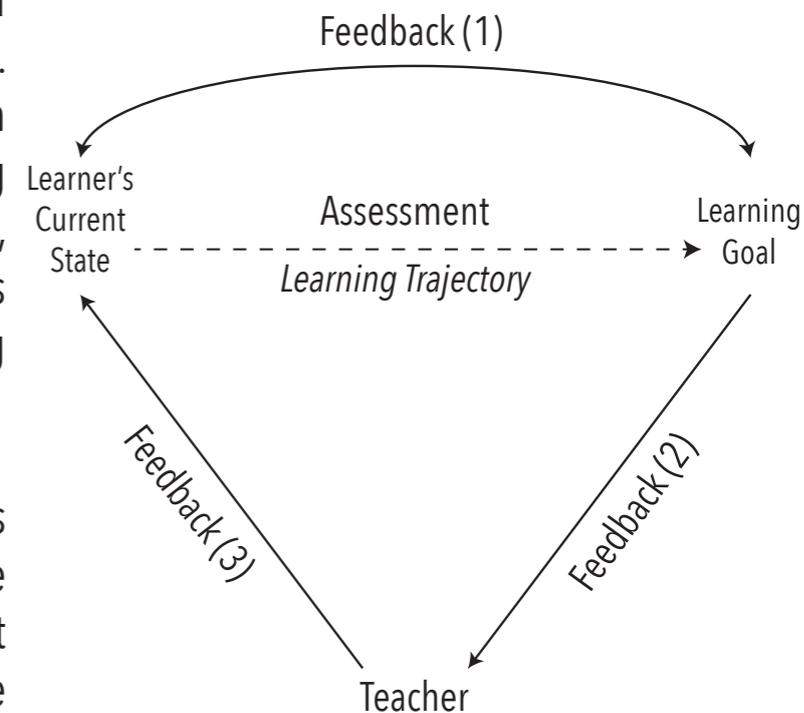
K-1	Addition
1-2	Subtraction
3-5	Fractions
6-8	Proportion
9-10	Algebra

In addition to providing schools and districts with an understanding of teachers' preparation to teach to the CCSS in Mathematics, TASKs can be used for professional development, program evaluation, and other research purposes.

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The TASK instrument is based on the concept of learning trajectory-oriented formative assessment. Formative assessment is considered one of the most promising methods for facilitating student learning. A synthesis of the research on formative assessment by Black & Wiliam (1998) found substantial evidence of large gains in student learning when teachers employ formative assessment practices. More recently, researchers have begun to piece together the ways that students progress as they develop mathematical understanding, called learning trajectories (Daro, Mosher, & Corcoran, 2011).

A framework for learning trajectory-oriented formative assessment is shown to the right. The basis of any potentially formative experience is both a clear understanding of the gap between a learner's current state and the goal of learning, or standard, and the pathway to achieve the goal. A well-designed assessment helps to locate the learner on the pathway towards the goal. The assessment becomes formative when the information it contains provides feedback to either the learner (Feedback1) and/or the teacher (Feedback2). For the instructional feedback loop to close, the teacher then has to provide an informed instructional response to the learner (Feedback3) that helps move them closer to the goal. Knowledge of the learning trajectory helps the teacher both locate the learner on the pathway and develop specific hypotheses about what kinds of assistance will help the learner move towards the goal. Formative assessment is an iterative process, so the cycle repeats until the gap between the learner's current state and the goal is closed and/or new learning goals are established.



The TASK instrument is designed to capture the **teacher-related domains** in this process.

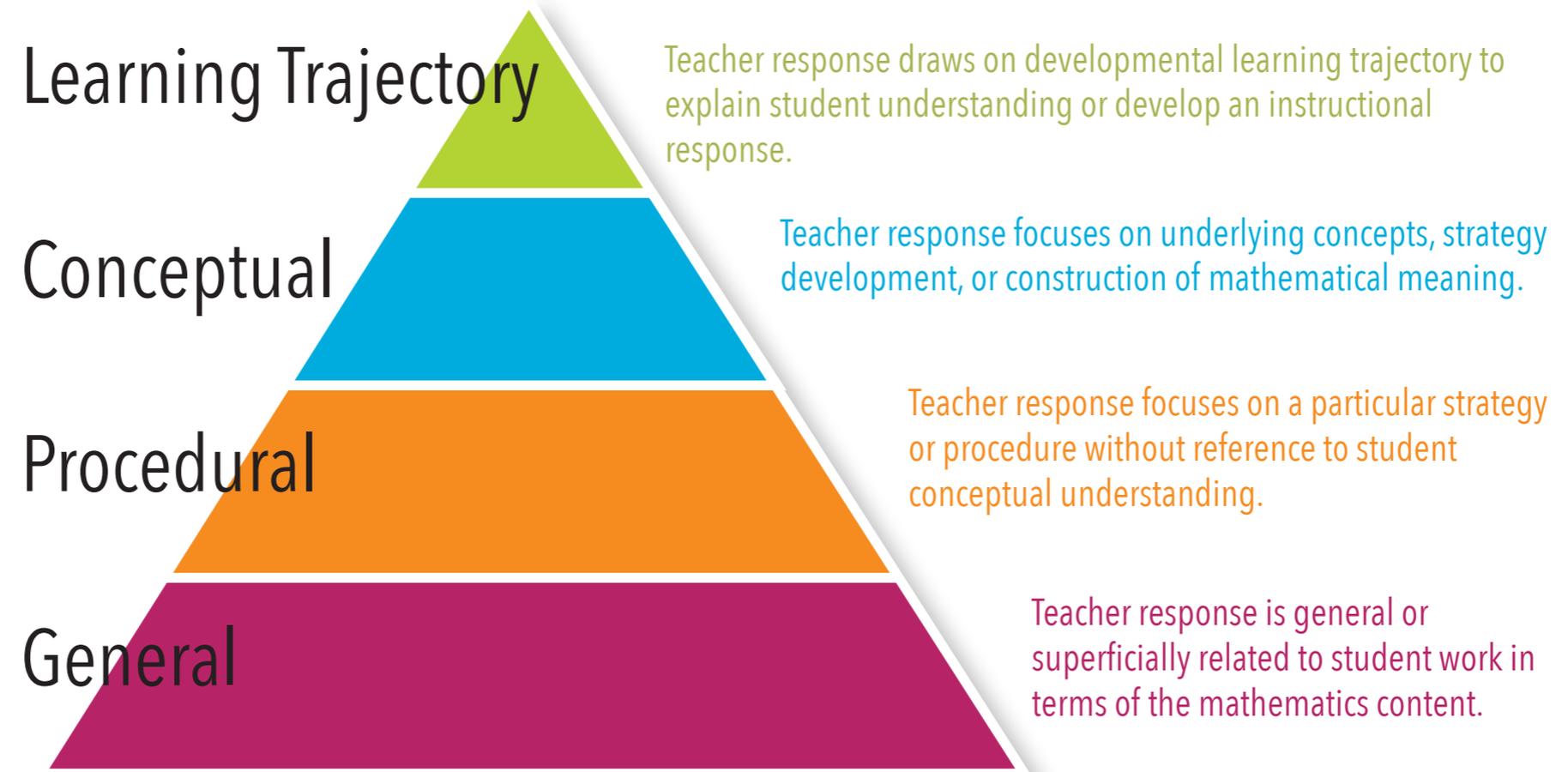
References

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice*, 5(1), 7-75.

Daro, P., Mosher, F. A., & Corcoran, T. (2011). *Learning trajectories in mathematics: A foundation for standards, curriculum, assessment, and instruction* (Research Report No. 68). Philadelphia, PA: Consortium for Policy Research in Education.

Figure excerpted from Supovitz, J. A. (2012). Getting at student understanding—The key to teachers' use of test data. *Teachers College Record*, 114(11), 1-29.

Most of the TASK domains are scored on a four point rubric:



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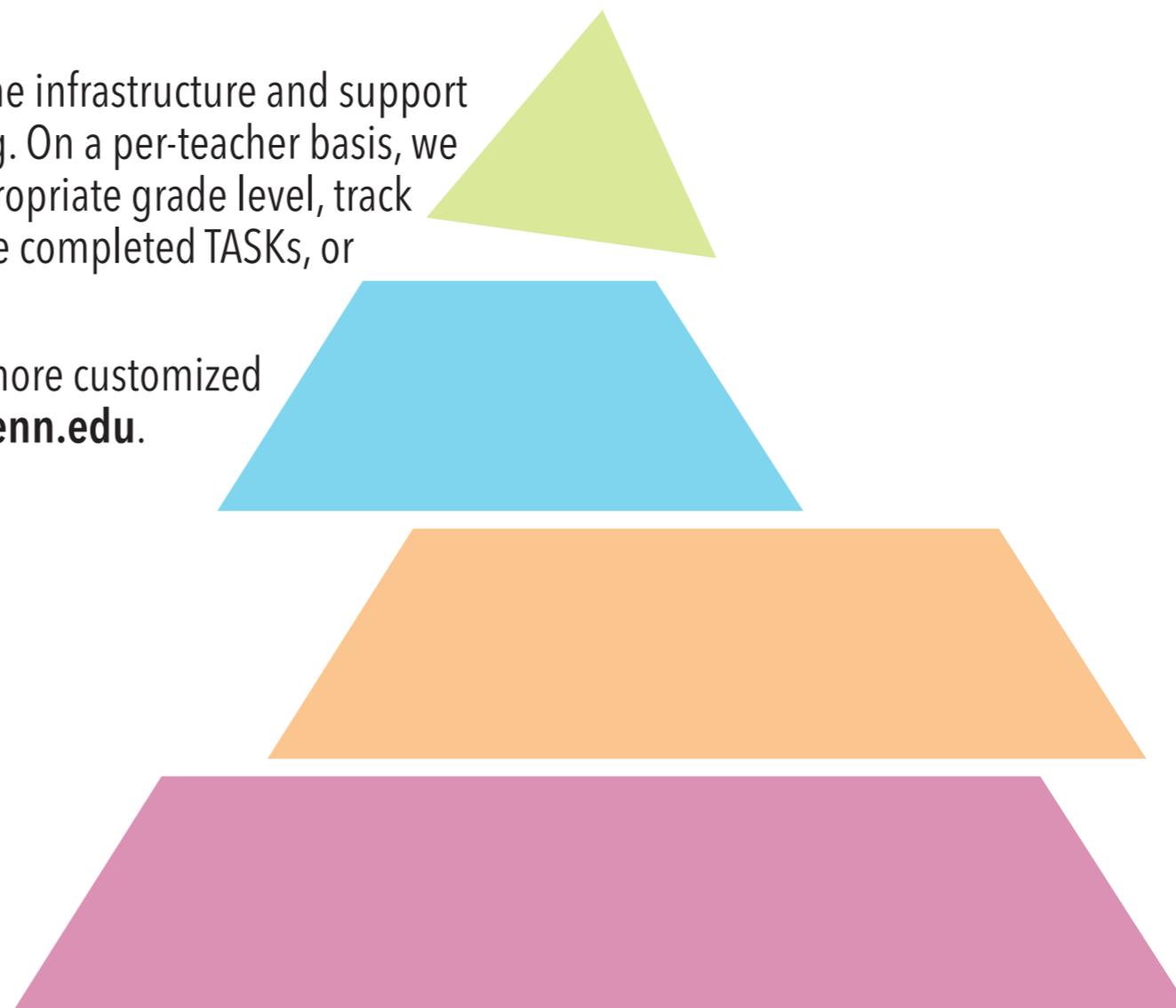
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The TASK can be used in a variety of ways, including:

- » Program evaluation
- » Educational research on data use, mathematics pedagogical content knowledge, or formative assessment
- » Professional development for teachers of mathematics
- » Assist districts to diagnose areas of strength and need in mathematics teaching and formative assessment practices for resource allocation, coaching, and design of professional development

CPRE is available to provide both the infrastructure and support for TASK administration and scoring. On a per-teacher basis, we can administer the TASK at the appropriate grade level, track completion of the instrument, score completed TASKs, or provide training for local scorers.

For information on these or other more customized services contact cpretask@gse.upenn.edu.

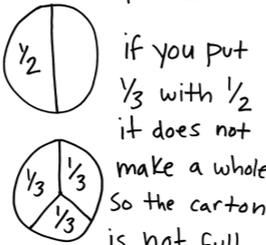
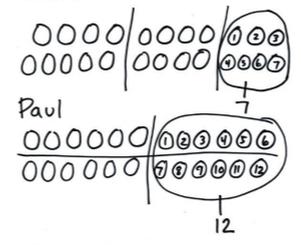


A TASK provides teachers with a grade-appropriate problem and a set of student responses, and asks teachers to complete seven steps:

1. Examine the mathematics problem and state the correct answer.
2. Explain what a student at your grade level needs to know and/or understand in order to solve the problem.
3. Examine the solutions of a set of typical students and determine if their solution processes are mathematically valid.
4. Comment on four students' solution processes in terms of what the work suggests about their understanding of number and operations (or algebraic reasoning).
5. Rank each student's solution in order of the level of sophistication of the mathematical thinking that is represented.
6. Explain the rationale for the rankings given to each student.
7. Suggest instructional next steps and explain the rationale for those steps for a student who has a correct, but less-sophisticated response to the problem, and a student who demonstrates conceptual weakness in the response.

Item Prompt: Each carton holds 24 oranges. Kate's carton is $\frac{1}{3}$ full. Paul's carton is $\frac{2}{4}$ full. If they put all their oranges together, would Kate and Paul fill 1 whole carton? Solve the problem. Show your work.

Student Responses:

Abby	Brad	Carla	Devon	Emma	Frank
<p>$\frac{2}{4} = \frac{1}{2}$</p>  <p>if you put $\frac{1}{3}$ with $\frac{1}{2}$ it does not make a whole so the carton is not full.</p>	<p>Kate $\frac{1}{3} = \frac{4}{12}$</p> <p>Paul $\frac{2}{4} = \frac{6}{12}$</p> <hr/> <p>$\frac{10}{12}$</p> <p>it is not full, only $\frac{10}{12}$.</p>	<p>NO</p> <p>$\frac{1}{3} + \frac{2}{4} = \frac{3}{7}$</p>  <p>$\frac{3}{7}$ is less than a whole</p>	<p>Kate</p>  <p>Paul</p> <p>$7 + 12 = 19$ they need 5 more</p>	<p>No, they do not have a full carton because $\frac{3}{4}$ is $\frac{1}{2}$</p> <p>$\frac{1}{2} + \frac{1}{2} = 1$ so $\frac{1}{2} + \frac{1}{3}$ is not 1 because $\frac{1}{3}$ is less than $\frac{1}{2}$</p>	<p>24 oranges</p> <p>$\frac{1}{3}$ is 8 oranges - Kate</p> <p>$\frac{2}{4}$ is 12 oranges - Paul</p> <p>$8 + 12 = 20$ so it is not full, you need 24.</p>

Click on the buttons below to see sample teacher responses and their rubric score for each domain:

Concept Knowledge

Analysis of Student Thinking

Learning Trajectory: Rationale

Instructional Decision Making

The TASK instrument was developed and piloted beginning in 2010. In Spring 2012, based on pilot results, CPRE conducted a large field trial in partnership with five public school districts in five northeastern and southern states. The districts varied in size, student demographics, and programs of mathematics instruction. The table below presents the number of schools and the average number of students per grade, as well as student demographics in each of the five districts.

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	District A	District B	District C	District D	District E
District Size^a					
# Schools	23	57	133	184	20
# Students	12,324	32,251	93,951	79,130	15,281
Student Demographics					
% White	47%	25%	53%	14%	39%
% Economically Disadvantaged	54%	73%	63%	82%	49%
% Limited English Proficient	8%	4%	6%	11%	14%
% Special Education	18%	20%	13%	20%	9%
District Teachers					
Sample Size ^b	325	376	394	438	318
# Teacher Respondents	273	274	268	329	242
TASK Response Rate	84%	73%	68%	75%	76%

Notes: ^a Number of schools and average student per grade based on 2011. ^b Random sample within district stratified by grade intervals.

To achieve our final sample, we randomly drew 1,851 teachers from the five districts. Of these, 1,386 responded, for a 75% response rate. Of the completed TASKs, 42 were removed due to substantial missing data. The data reported here also do not include the 83 responses on the geometry TASK. The final sample we report on here consists of 1,261 responses for teachers in grades K-10. More information on the technical qualities of the TASK can be found at cpre.org/task.

The first question of the TASK asked teachers to determine the correct answer to the mathematical problem before they were shown any student responses. Incorrect responses may provide an indication of the teacher's weakness in content knowledge. However, since this was the only item that addressed content knowledge we do not consider it to be a sufficient measure of teacher's content knowledge. *Note: Content knowledge is not a TASK domain.*

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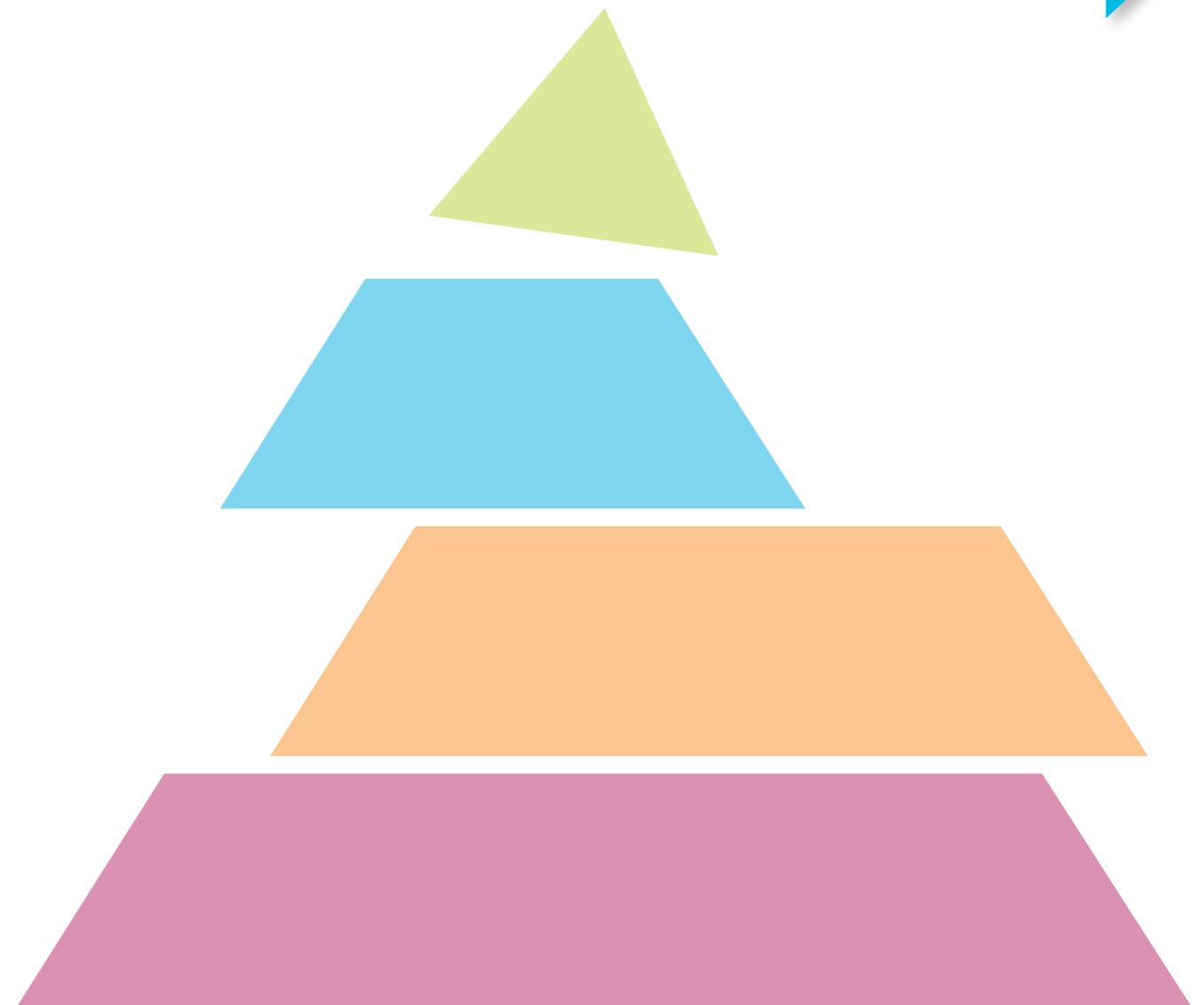


Take-Aways:

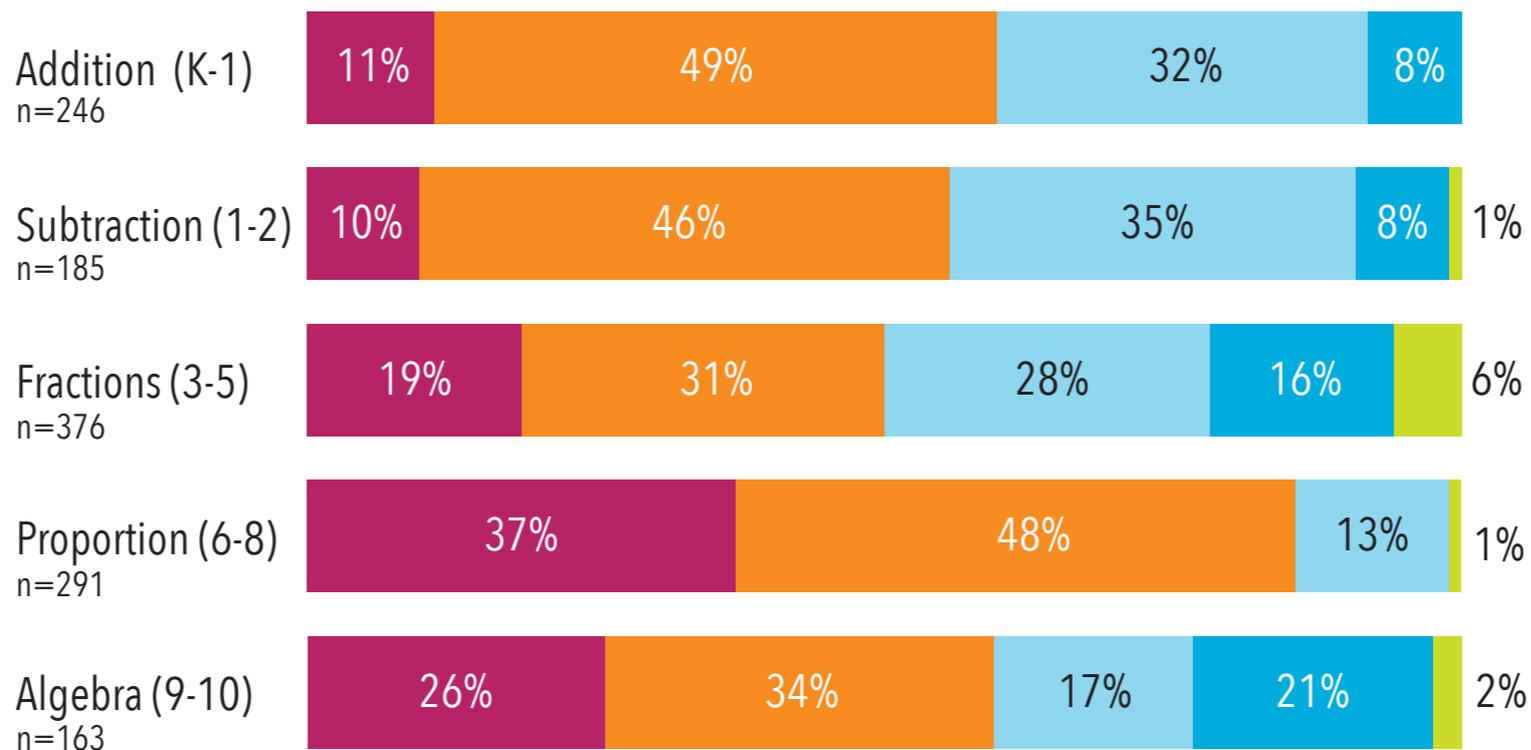
- » Teachers' ability to correctly solve the given mathematical problem at their grade level was generally strong.
- » Surprisingly, 15%, or 24, of the 163 grade 9-10 teachers gave an incorrect answer to the algebra problem, which involved extending and generalizing a pattern.

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The Concept Knowledge domain measures teachers' ability to identify and articulate the mathematics concept and related sub-concepts that are represented in a particular item. In formative assessment, it is important for teachers to have knowledge of the type of evidence likely to be elicited by a specific problem. To assess this domain, teachers were asked to describe what a student at their grade level would need to know and/or understand in order to solve the given problem. Their responses were scored with the four level TASK rubric.



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Scored using TASK rubric

NOTE: The Conceptual Response category was further divided into responses that had a general conceptual focus (shown on the graph in light blue) and responses where concepts were more fully articulated (shown in darker blue). Responses were considered to be in the learning trajectory category (shown in green) if they included more than one articulated concept.

To Sample Teacher Responses

Take-Aways:

- » In grades K-5, over 40% of teacher responses reflected some degree of conceptual focus in the analysis of the problem. Of those, a much smaller proportion of responses were fully articulated or referenced more than one articulated underlying concept (9% in grades K-2 and 22% in grades 3-5).
- » In grades K-2, nearly half of the responses focused on procedures for solving addition or subtraction problems rather than underlying concepts.
- » In grades 6-8, only 14% of respondents referenced concepts associated with the proportional reasoning item, while almost half (48%) of the respondents focused on procedures; 37% referenced only general topics, such as "ratios" or "proportions."
- » In grades 9-10, 40% of the responses reflected some conceptual focus, while 34% focused on procedures. About a quarter (26%) of teachers' responses referenced only a general topic, such as "algebra" or "patterns."

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TASK Prompt: What does a student need to know and understand in order to solve this problem?

Learning Trajectory Response

"They need to understand: A fraction is a part of a whole. A whole can be a group of things or one thing. 24 oranges is a whole, which is mentioned in this problem. 12/12 is a whole. When adding fractions you don't add the denominator. Either how to find 1/3 and 2/4 of 24 or how to make a common denominator."

Conceptual Response

"They need to know that $2/4 = 1/2$ they also need to know the relationship of fourths and thirds...which is bigger." (articulated)
 "Understand fractions, part of a whole and know how to add." (general)

Procedural Response

"They have to reduce fractions and be able to find common denominators and then add fractions."

General Response

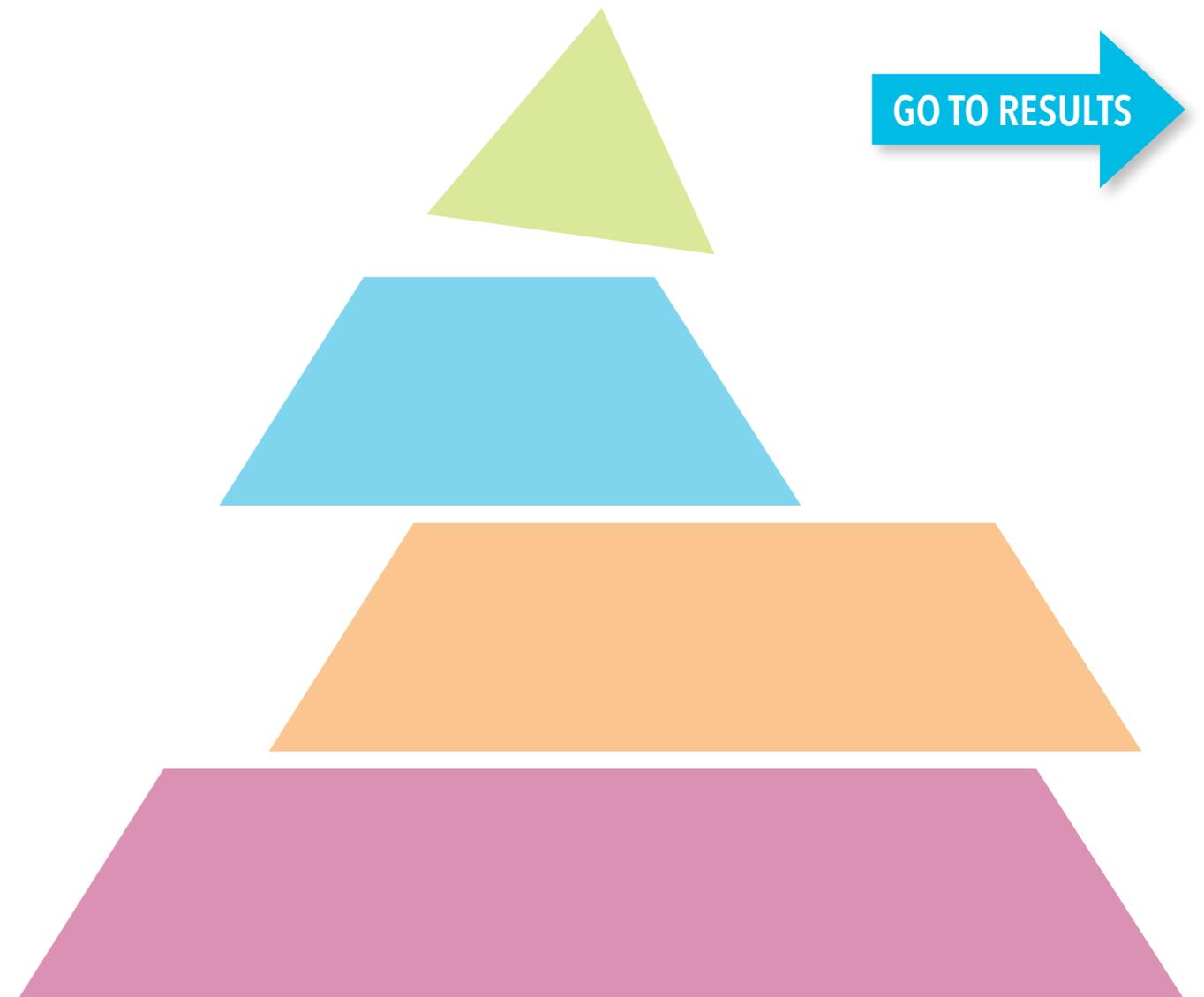
"Fractions. Reduction. Multiplication. Number Order. Ability to count to 20. Addition. English comprehension."

To Sample TASK

To Domain Results

Mathematical Validity is a measure of teachers' ability to analyze a student's solution strategy and determine whether the approach is mathematically sound, regardless of the final answer. In formative assessment, teachers need to be able to look beyond the correctness of a student's answer to assess the appropriateness of the solution method. For example, students may use an incorrect approach but still arrive at a correct answer. In each TASK, teachers were asked to determine whether each student solution process was mathematically valid.

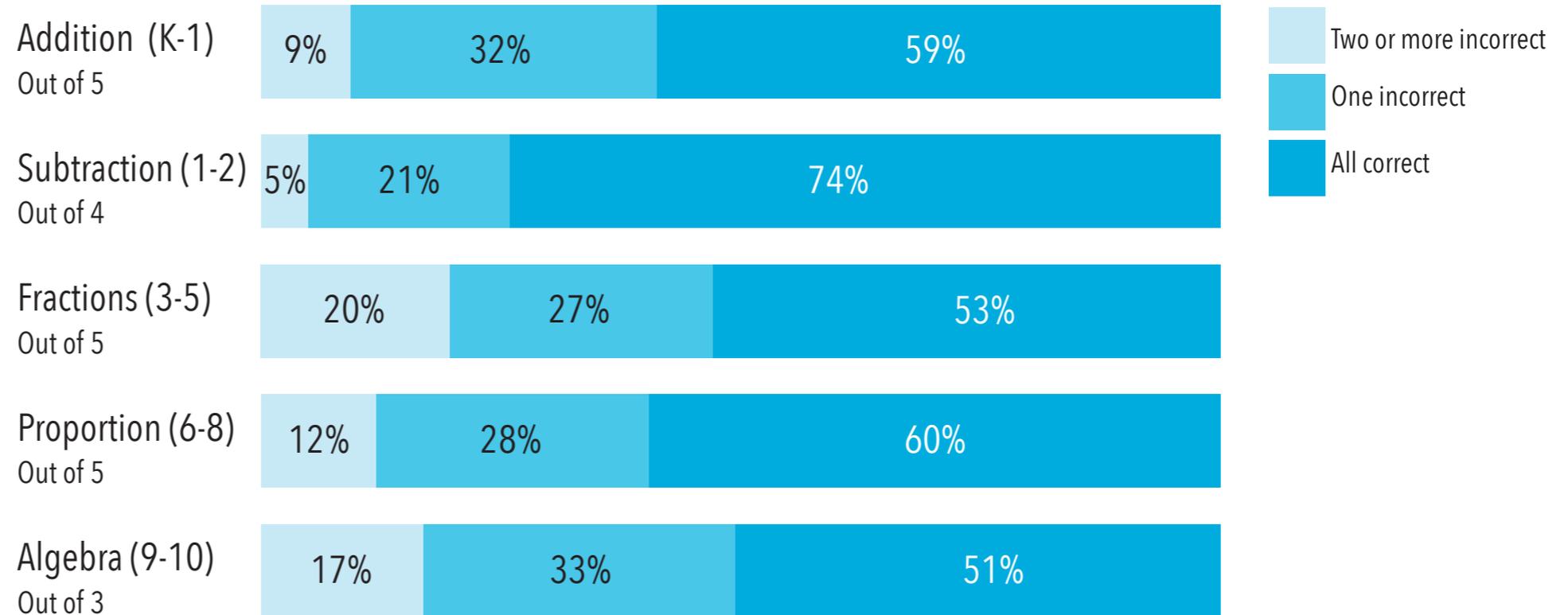
In all TASKs, there were two mathematically incorrect solutions and one solution was somewhat ambiguous in that the student attempted to use an appropriate strategy, but either made a conceptual or computational error in the process. To score this question, we looked at the number of correctly identified responses out of the number that were unambiguous (between 3 and 5 depending on the TASK).



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The graph shows the proportion of teachers who (1) correctly identified all strategies (2) misidentified one strategy or (3) misidentified two or more strategies.

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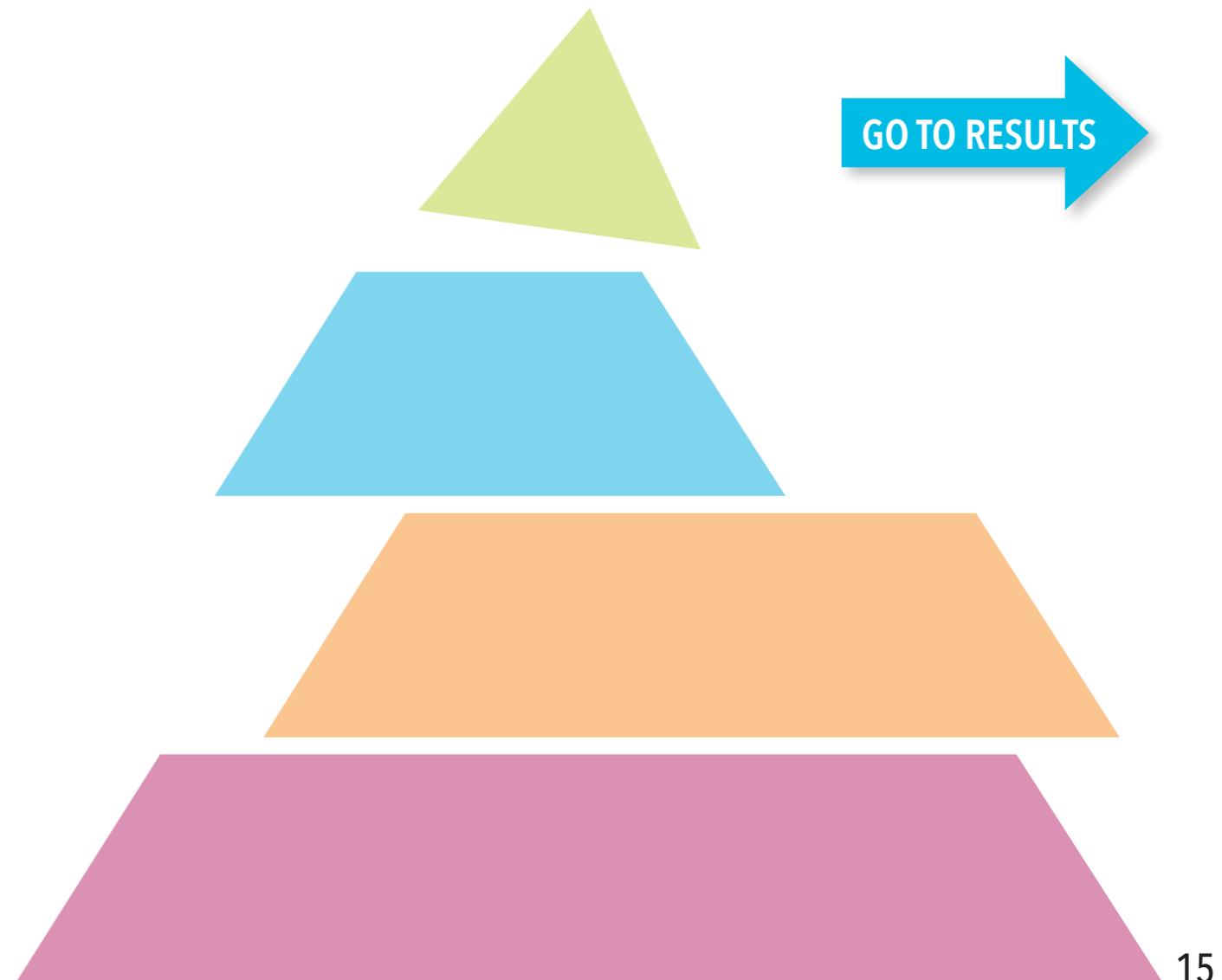


Take-Aways:

- » More than half of teachers at all grade levels were able to correctly identify the validity of all student strategies that were non-ambiguous.
- » Fewer than a fifth of the teachers at each grade level made multiple misjudgments about the validity of students' solution strategies.
- » Taken together, these results suggest that most teachers were able to determine the mathematical validity of a range of student solution strategies.

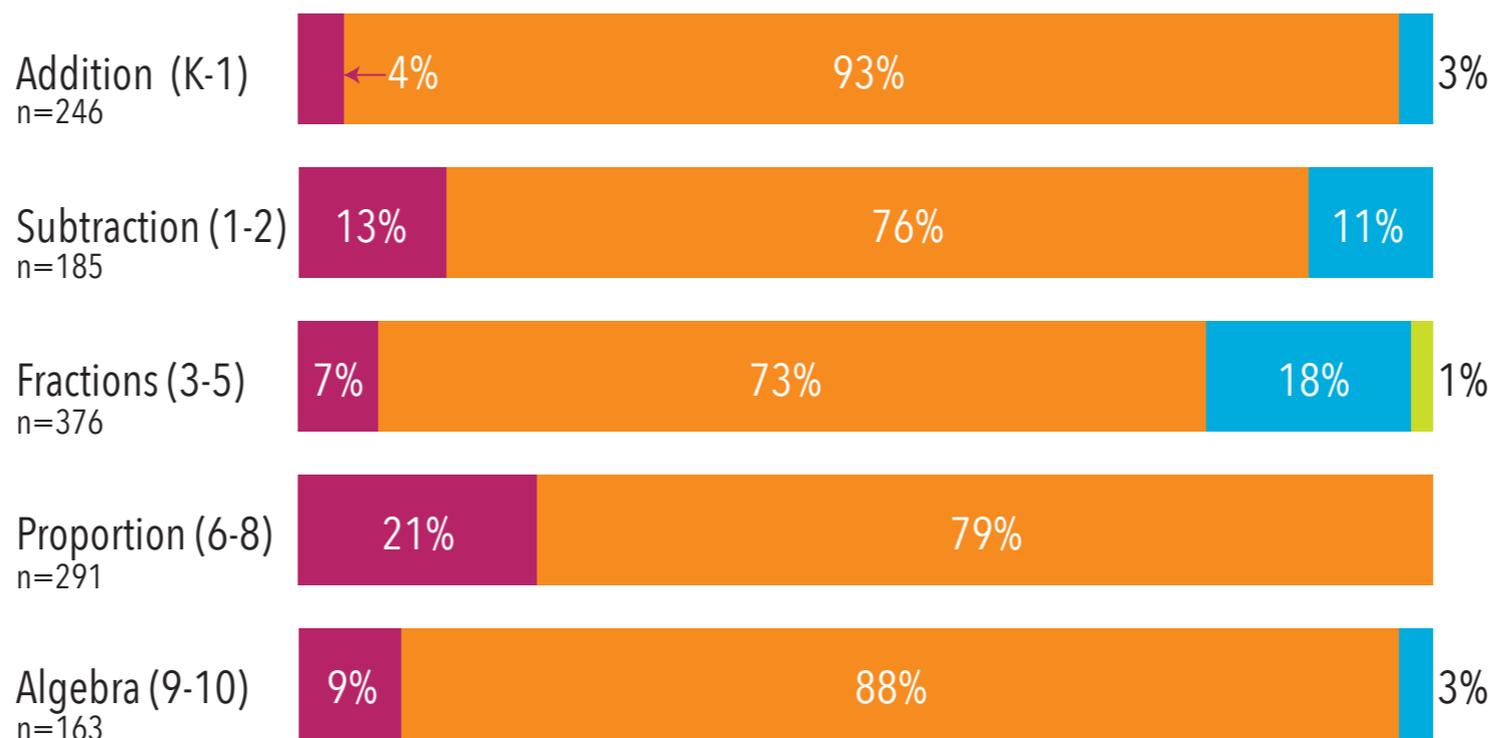
Analysis of Student Thinking is a measure of teachers' ability to identify the underlying conceptual understandings or misconceptions present in student responses on assessments. During formative assessment, the interpretation of student thinking is a key precursor to a teacher's ability to provide targeted feedback to move the learner forward. Teachers must be able to look beyond whether students produce a correct answer or use correct procedures to also draw inferences about what the student understands and whether there are underlying misconceptions that need to be addressed.

On the TASK, teachers were asked to comment on four students' solution processes in terms of what the work suggested about each student's understanding of number and operations (or algebraic reasoning at the secondary level). Each response was scored with the four-point TASK rubric to judge the extent to which the response focused on underlying conceptual understandings that were represented in the student solution strategies.



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To Sample Teacher Responses

Take-Aways:

- » Across all grade levels, the vast majority of teacher responses were procedural, focusing on what the student did to solve the problem rather than commenting on the student's underlying conceptual understanding.
- » Teacher responses for fractions had the greatest percentage of conceptual responses (18%) and a few responses at the highest learning trajectory level (1%). This may be a reflection of the fact that fractions is a topic that is typically taught with a conceptual focus in the elementary grades.
- » All teacher responses for proportions were either procedural or general. The large percentage of procedural responses (79%) suggests a procedural emphasis in middle school mathematics teaching. Additionally, about one fifth of the teachers at this grade level gave only general analyses of the student work (e.g., "understands proportions" or "demonstrates strong reasoning").

TASK Prompt: Comment on each student's solution process in terms of what the work suggests about the student's understanding of numbers and operations.

Learning Trajectory Response

"Abby understands that the size of fractions is determined by the denominator, and they represent breaking the whole into equal parts. She also understands equivalent fractions as well. Thereby, she is able to compare the two fractions and ultimately, compare her results to one whole."

Conceptual Response

"She shows that she understands the concepts of fractional part of a whole" (articulated)
 "Abby understands how fractions make a whole part." (general)

Procedural Response

"Abby drew 2 pies and was able to figure out that the 2 different fractions didn't equal a whole together."

General Response

"She has a basic understanding of fractions."

To Sample TASK

To Domain Results

This component of the TASK measures a teacher’s ability to position student solution strategies along a learning trajectory and order them in terms of the sophistication of thinking and reasoning. Learning trajectories, an important underlying component of the Common Core State Standards in Mathematics, provide a framework for how student thinking becomes more sophisticated and efficient over time so that feedback can be tailored to move students forward along the path to achieving the desired goal.

On the TASK, teachers were asked to rank the student responses in order of their level of sophistication. While there was not one correct way to precisely rank the order of responses, the student solutions could be cleanly placed into three categories: (1) the student response contained evidence of solid numerical, fractional, proportional, or algebraic reasoning; (2) the student response had evidence of transitional thinking in numerical, fractional, proportional, or algebraic reasoning; (3) the student response had no evidence of numerical, fractional, proportional, or algebraic reasoning.

If the teacher correctly ordered the student responses in relation to these categories, then the response was considered to be ordered correctly.

For this question the four rubric levels were defined to represent the degree to which the ranking reflected attention to student reasoning.

Click on the icon for more information on the Learning Trajectory Orientation: Ranking scoring rubric.



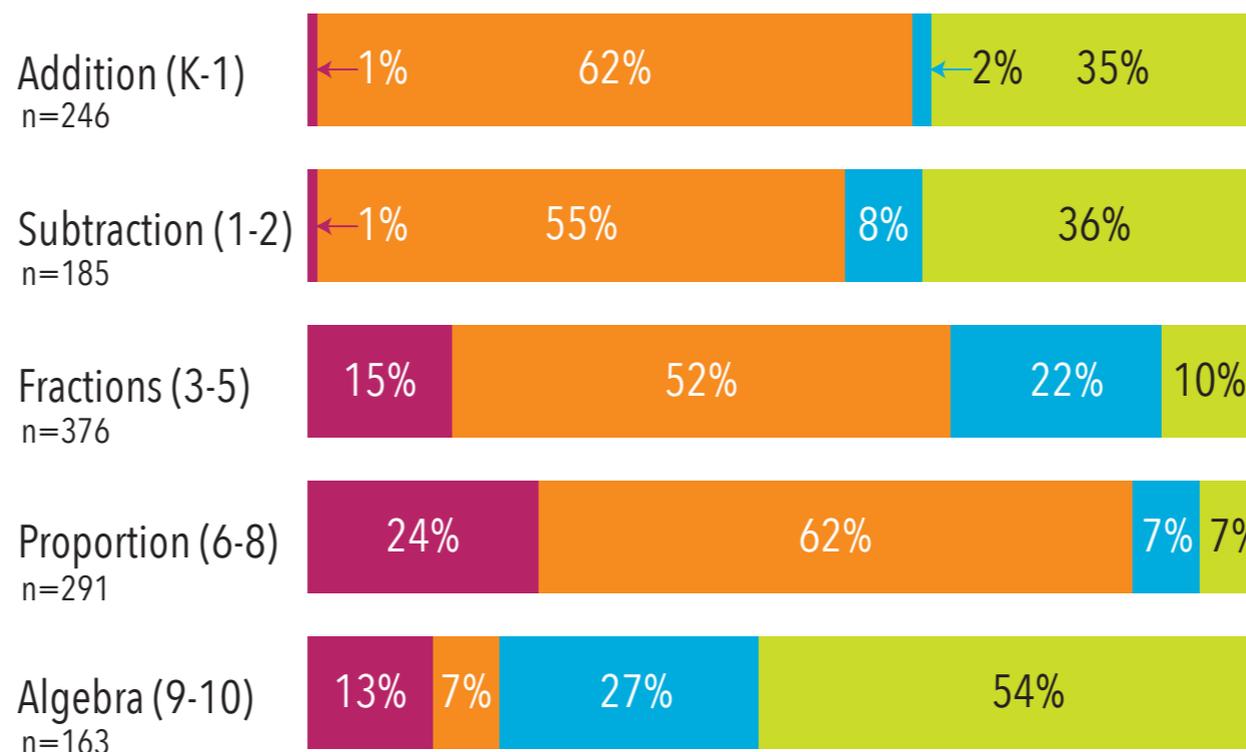
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Score	Ranking	Explanation
4	Correct order and most sophisticated thinking identified	Advanced learning trajectory orientation
3	Correct order	Evidence of learning trajectory orientation
2	Incorrect order but the lowest two responses were in the bottom two-thirds of the ranking	Ability to identify correct and incorrect reasoning
1	Incorrect order and one of the lowest two responses was ranked in the top two	No emphasis on student reasoning or prioritizing use of specific method over conceptual or procedural understanding



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Take-Aways:

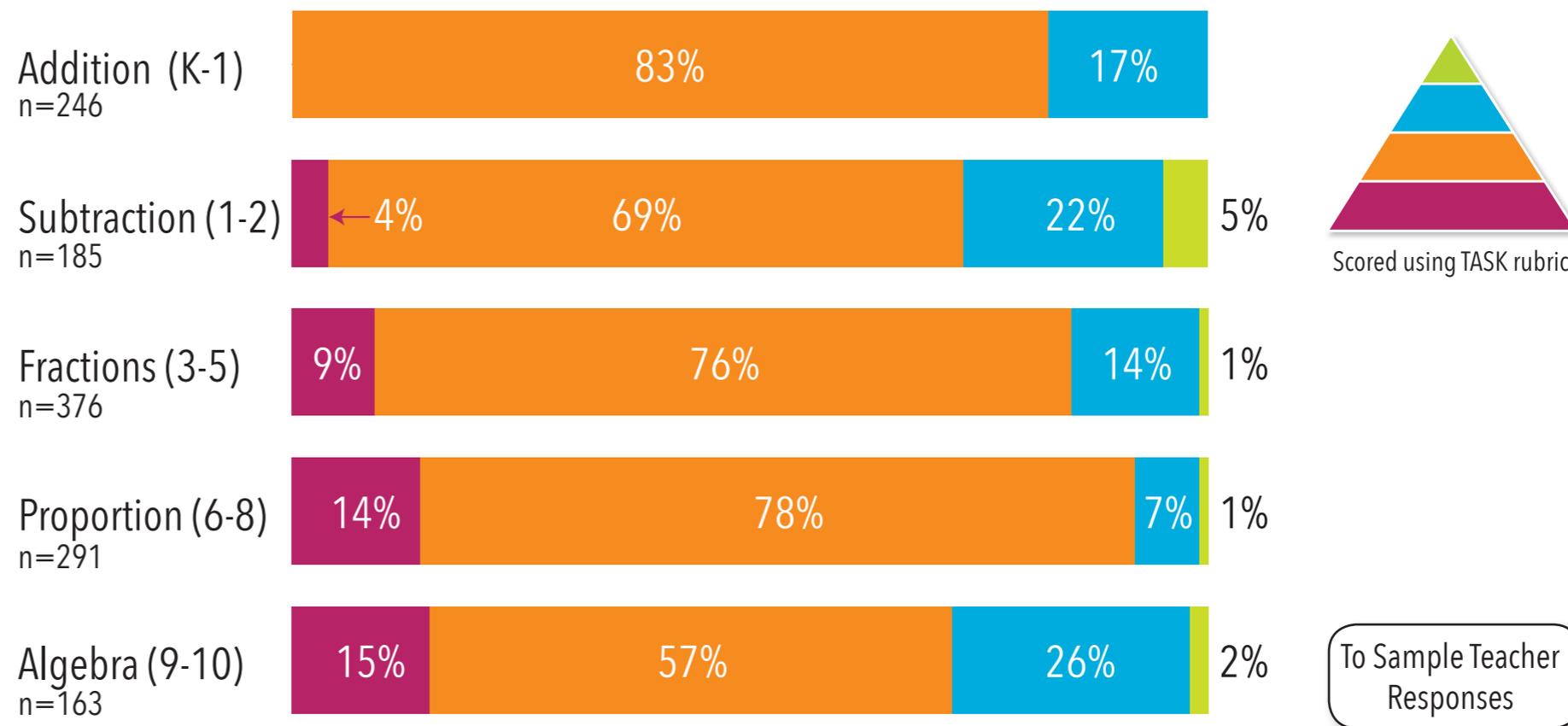
- » In grades K-2, for both addition and subtraction, the distribution of rubric scores followed a similar pattern, with more than a third of the respondents able to correctly order student responses in relation to the sophistication of reasoning.
- » In grades 3-5, while there were fewer responses reflecting an advanced orientation, a third of the responses reflected the correct general order (shown in blue and green).
- » In grades 6-8, only 14% of teachers selected the correct order in relation to evidence of proportional reasoning and nearly a quarter (24%) ranked one of the lowest two responses (those containing minimal evidence of proportional reasoning) as being advanced. Six out of 10 teachers had some, although imperfect, sense of appropriate rankings.
- » In grades 9-10, by contrast, 81% of teachers correctly ordered the student strategies and more than half of the teachers were able to order them in relation to the sophistication of reasoning. The higher scores on this TASK may be due to a stronger sense of learning trajectories, or alternatively to the fact that only four pieces of student work were presented (compared to the six pieces presented in the other TASKs).
- » Overall, less than half of teachers in grades K-8 correctly ordered the student strategies in relation to student reasoning.

In addition to the rankings, teachers were also asked to provide their rationales for their rankings of student work. These responses were scored based upon each teacher's focus when ranking the solution strategies (general, procedural, conceptual, or learning trajectory). Rationales were scored in two stages: first, the rater examined the explanations provided by the teacher for the student solutions they ranked in the top three to determine what the teacher was attending to when evaluating successful student work. Second, the rater examined the rationales for the student solutions ranked in the bottom three to see how the teacher was evaluating weaknesses in student work. The result graphs show the average of these two scores.

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Take-Aways:

- » Across grade levels, the vast majority of teachers explained their ranking rationales by pointing out procedural aspects of students' work rather than what students understood or how that understanding was situated in a learning trajectory.
- » Comparing these results to the Learning Trajectory Orientation Rankings, we see that teachers were more successful in choosing the correct ranking than they were in providing a reasoned rationale for that ranking. This suggests that while many teachers may have a sense for students' sophistication of reasoning, this knowledge is not well articulated in relation to the developmental nature of student thinking.
- » The relatively high percentage (28%) of grade 9-10 algebra teachers who gave conceptual or learning trajectory-oriented explanations to explain their rankings lends some credence to the earlier mentioned hypotheses that high school teachers, with more subject-specific knowledge, may be better able to recognize and articulate student conceptual understanding.

TASK Prompt: Explain your ranking of each student’s response in relation to the responses of the other students.

Learning Trajectory Response

“I ranked Abby second because she uses a basic model while Emma needs reasoning alone to solve the problem. This shows a deeper conceptual understanding. Although Devon’s answer was incorrect, his reasoning was sound.”

Conceptual Response

“Brad understand equivalent fractions, and the need for common denominators in order to add fractions. Emma understands that what fractional pieces represent. Abby has a concrete and correct understanding of equal pieces (fractions) represent the whole. She understands equivalency of a basic fraction... $1/2 = 2/4$.”

Procedural Response

“Brad showed that he understands how to properly add fractions with different denominators. Abby used pictures to accurately show representations and got her answer by combining them. Devon attempted to use pictures but miscounted which led to the wrong answer.”

General Response

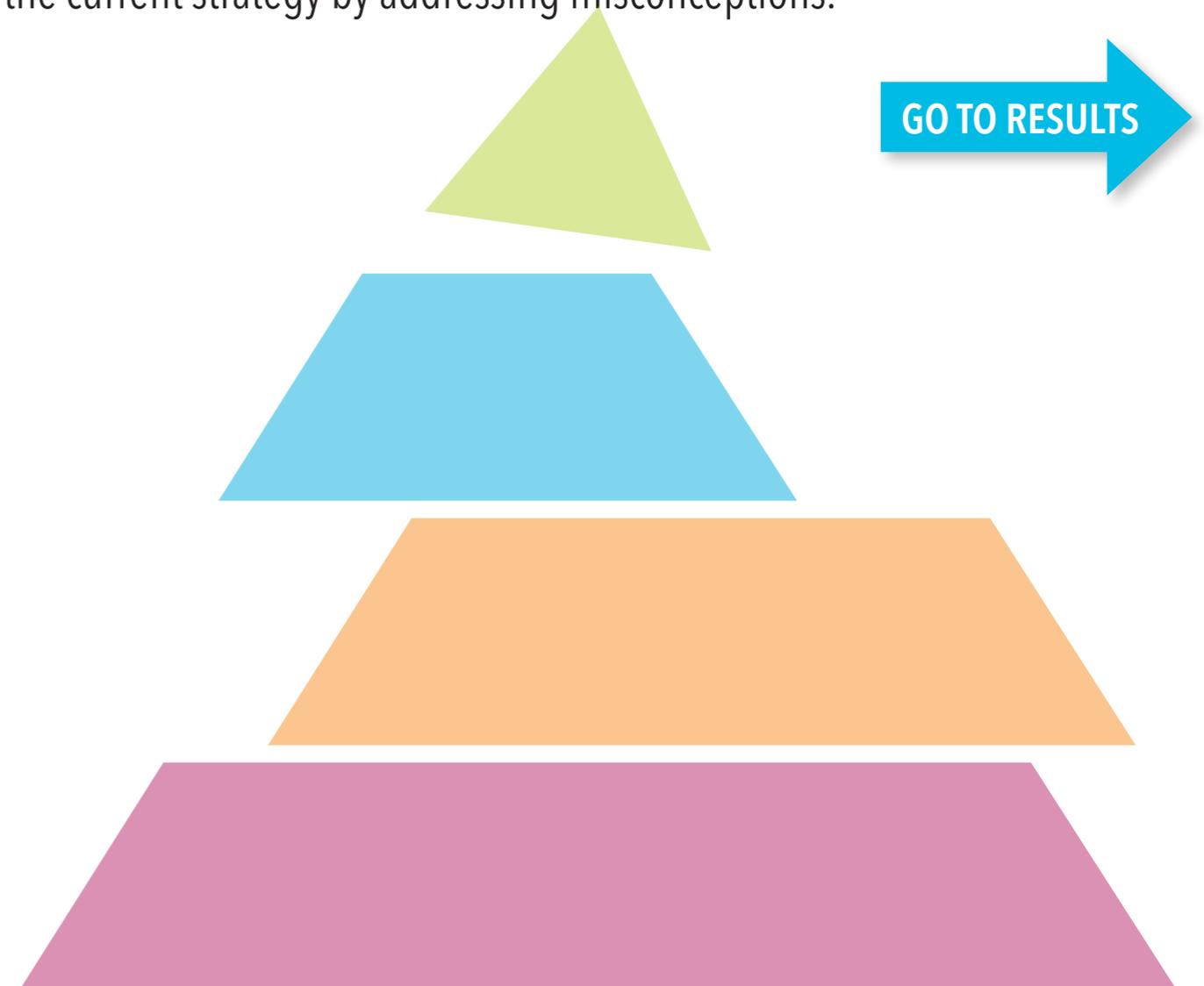
“Brad converted the fractions to 12ths. Emma explained completely with words. Abby explained with words and pictures.”

[To Sample TASK](#)

[To Domain Results](#)

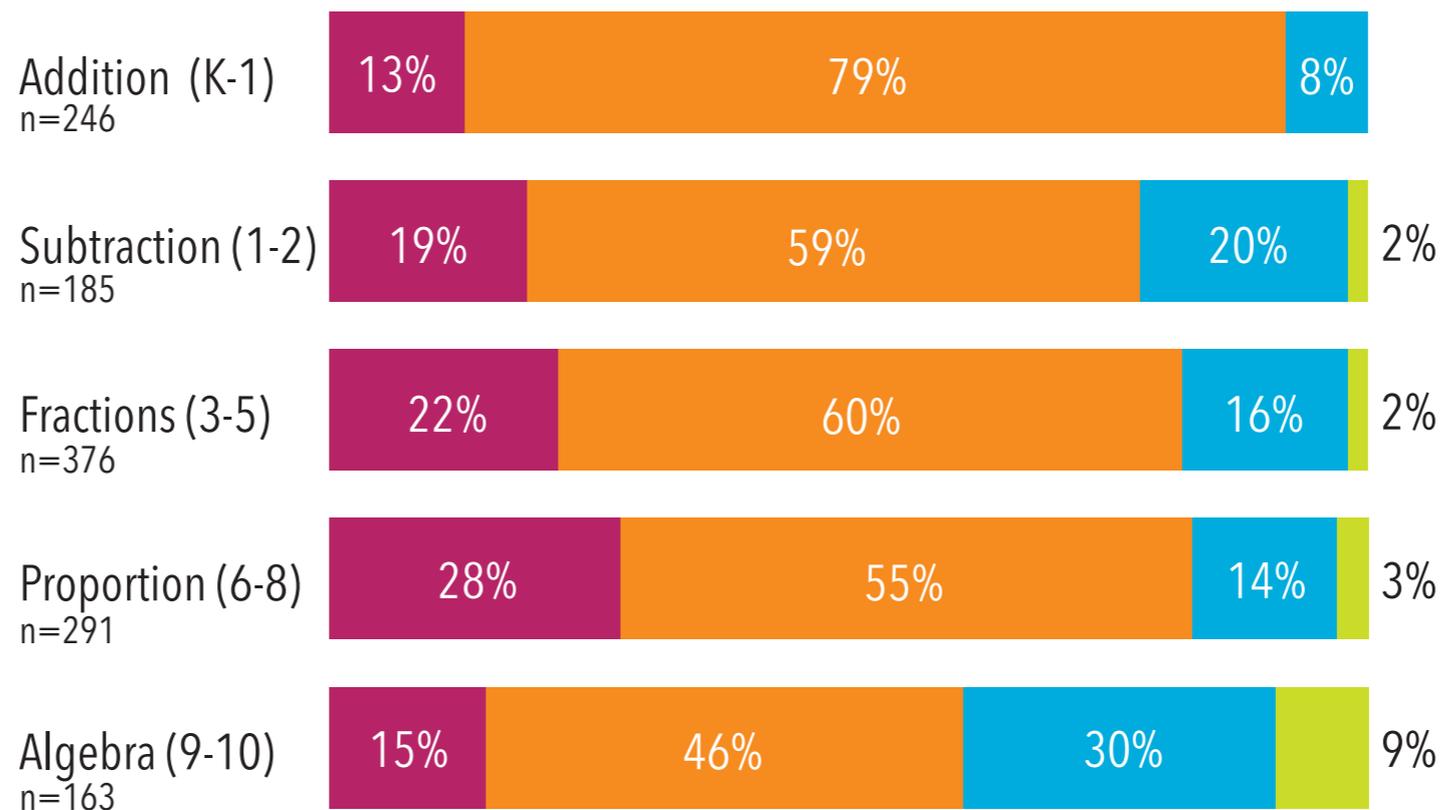
The final domain in the TASK measures teachers' ability to choose an appropriate instructional response to move students from their current level of understanding along the developmental trajectory towards greater understanding. In formative assessment, feedback to the learner can be more effective when it is specifically tailored to students' developmental levels.

On the TASK, teachers were asked to provide next steps, and explain their rationale for those steps, for two students: one student who had a correct, but less-sophisticated response to the problem, and a second student who demonstrated conceptual weakness in their response. The rubric reflects the four levels of teacher response (general, procedural, conceptual, and learning trajectory). In order for a response to be considered at the highest level (learning trajectory-oriented) it could be procedural or conceptual, but had to build on the current student understanding to either move the student incrementally towards a more sophisticated strategy or solidify the current strategy by addressing misconceptions.



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To Sample Teacher Responses

Take-Aways:

- » Across all grade levels, the majority of teachers' suggestions to students focused on procedural advice (i.e., on teaching a student a particular strategy or procedure), rather than on developing mathematical meaning or understanding.
- » In grades K-1, more than three quarters (77%) of the teachers gave procedural suggestions and fewer than 10% of the instructional responses sought to deepen students' conceptual understanding.
- » By contrast, while procedural responses still predominated (nearly 60%) in subtraction, fractions, and proportions, about 20% of teachers were able to make conceptual suggestions.
- » Teachers in grades 9-10 provided the strongest responses. Nearly a third gave conceptual responses with an additional 8% reflecting a learning trajectory orientation (i.e., building on current student understanding to address misconceptions or help the student develop a more sophisticated strategy).

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TASK Prompt: Examine Abby's work. As a teacher, what would you do next? Please explain your rationale for the steps you suggest.

Learning Trajectory Response

"First, I would encourage her to draw a picture and group things according to the fraction... $1/2 = 12/24$, $1/3 = 8/24$. I would explore the relationship among those equivalencies to help her understand the interrelatedness. Drawing a picture is a basic understanding or step to equal - sharing/division - fractions but easy for children to do at an early age. Equivalent fractions is more sophisticated but can be explored to understand how these numbers make sense."

Conceptual Response

"I would first ask Abby to look at her representation of $1/3$ and ask her to explain how it is indeed $1/3$. Abby needs to understand that the circle must be divided into 3 EQUAL parts. Next, I would ask how can she prove it does not make one whole when it is added to one half? I would guide her in seeing that $1/3$ (a whole divided into 3 equal parts) is less than one whole divided into 2 equal parts and therefore, when added to $1/2$ it could not equal one whole."

Procedural Response

"Abby would be directed into writing fractions, determining a common denominator and then making equivalent fractions and solving the problem."

General Response

"Abby should practice to enrich her understanding."

To Sample TASK

To Domain Results

These findings reflect a general picture of the current state of teachers' learning trajectory-oriented formative assessment capabilities in grades K-10 in five urban and urban fringe districts in five states. Overall, they indicate:

- » Across the domains examined on the TASK, there were more *procedural* responses than any other category. In fact, with the exception of Analysis of Student Thinking in fractions, the procedural responses outnumbered conceptual and learning trajectory responses combined. Given the emphasis in the Common Core State Standards on rigor as a balance between conceptual and procedural understanding, this suggests that there is a great deal of room for growth in teacher capacity to identify, interpret, and respond to students' conceptual understanding.
- » Although about 40% of teachers are able to identify the mathematics concept that an item intends to assess, when examining the student work of that item, more than three quarters of the teachers focused on what students do (procedural) rather than what they understand (conceptual).
- » General and procedural interpretations were most predominant in the responses from middle school (grades 6-8) teachers on the proportions TASK, suggesting that this is a particular area of need for professional development focusing on conceptual understanding.
- » After examining specific pieces of student work, the majority of teachers across all grade levels suggested teaching the student particular strategies or procedures rather than developing mathematical meaning or understanding.
- » Teachers were more successful at ranking student work in order of sophistication than they were in providing a reasoned rationale for that ranking. This suggests that while many teachers may have developed a tacit sense of levels of sophistication in student reasoning, their knowledge about the developmental nature of student thinking is not well articulated.
- » While there is much room for further development, teachers in grades 9-10 (algebra) performed stronger on the TASK than other teachers. This could be due to the fact that they are more subject matter specialized than elementary school teachers or that they have more experience analyzing different strategies in student work.

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