ACT WorkKeys®

WorkKeys Applied Math Technical Bulletin

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Applied Math Technical Bulletin

Section 1: General Description of the Applied Math Assessment

ACT developed the Applied Math assessment as an updated measure of work-related applied mathematical skills to serve a similar function as the Applied Mathematics assessment. The Applied Math assessment constitutes one of three assessments of the ACT WorkKeys National Career Readiness Certificate® (NCRC). In developing the Applied Math assessment, ACT utilized four significant sources of information: (1) knowledge gained through 23 years of administering the Applied Mathematics assessment, (2) knowledge gained through ACT's job profiling services that included thousands of jobs for which the Applied Mathematics assessment was identified as relevant, (3) input and feedback from a panel of external Subject Matter Experts (SMEs) with experience in workforce development, and (4) professional literature published over the past 50 years analyzing how students and workers use quantitative information to solve problems in the workplace.

The Applied Math assessment, like all ACT WorkKeys assessments, is designed to measure relevant skills required for success in today's job market. WorkKeys assessment data is based on skills, not scores, and has the capacity to demonstrate readiness to learn and succeed in the workplace, rather than achievements or deficits.

ACT organized a Design Team, composed of individuals from various areas within ACT including Test Development Content, Measurement and Research, Industrial/Organizational Psychology, and Assessment Design, to review and update the Applied Mathematics assessment. The Design Team was assisted by a group of external SMEs who provided feedback and recommendations on the assessment construct, proposed test blueprint, and sample items.

The Applied Math assessment was designed to measure the extent to which individuals can use mathematical skills needed in workplaces. The ability to think problems through to find and evaluate solutions is critical for workplace success (Australian Association of Mathematics Teachers, 2014; Smith, 1999). The Applied Math assessment measures skills that individuals use when they apply mathematical reasoning and problem solving to work-related problems.

1.1 Applied Math as a Foundational Workplace Skill

ACT defines foundational workplace skills as "the skills that are essential for conveying and receiving information that is vital to work-related training and success" (ACT, 2014). Job skills are different from foundational skills. Job skills are the skills required to perform a specific job. For example, registered nurses must develop multiple skills, including giving an injection to a patient, in order to successfully fulfill their job tasks. Foundational skills are more general than job skills. They are the skills that enable a person to learn specific job skills.

Foundational skills are often referred to as basic or academic skills that may be learned through formal schooling or on one's own. Foundational skills are often defined in terms of academic subjects, including reading, writing, mathematics, and science. These skills enable individuals to acquire job specific skills, communicate information with fellow workers, and engage in lifelong learning. Foundational skills are also described as "portable" in that, rather than being job specific, they can be applied across a wide variety of jobs and occupations.

1.2 Mathematics in the Classroom and the Workplace

To help delineate the construct of the Applied Math assessment, ACT reviewed literature on numeracy skills and their application to the workplace. Although classroom instruction in mathematics overlaps in important areas with workplace mathematical applications, it does not account for a large number of workplace uses. A growing body of research has documented the differences between mathematical reasoning as it is taught in the classroom and how it is applied in the workplace. As emphasized below, these studies and evaluations indicate that the successful application of mathematics in the workplace is situational, incorporates problem solving, and integrates various mathematical and quantitative reasoning skills (Australian Association of Mathematics Teachers, 2014; Smith, 1999).

Changes in workplace technology over the last half century, both large and unpredictable, have been rapidly absorbed and adopted. In the 1970s, the first desktop calculators cost hundreds of dollars and typically performed only the four basic arithmetic operations. Today, hand-held graphing calculators selling for under $100 have more capabilities than early mainframe computers. Such developments underscore necessary changes in the mathematics skills needed for the workplace. Where employees used to perform calculations by hand and check the results for accuracy and reasonableness, they now use calculators or spreadsheets from the outset. To be successful on the job, employees need

- problem-solving strategies to set up and run the calculations best suited to answer their needs
- sufficient estimation skills to be able to recognize when results are highly unlikely, or to determine that incorrect data may have been entered

Unlike mathematical problems presented in classrooms, workplace problems are seldom clearly defined. In the classroom, mathematical problems are often structured by a textbook and are taught somewhat in isolation. Although classroom mathematical skills tend to progress and build on one another, the student is typically solving mathematical problems as defined by the specific unit of study at the time.

In applying mathematical skills to workplace problems, employees must utilize their understanding of mathematics and quantitative reasoning to derive the process or procedure for solving the problem. An employee may have a boss or co-worker who will help him or her set up and solve the problem, but in many circumstances, the employee will be expected to set up and solve the problem without assistance. In other cases, besides setting up and solving the problem, the employee will need to determine what data is relevant to solving the problem. Although the mathematical skills observed in the workplace may appear to be fundamental, it is the application of the skills to the workplace problem that is not straightforward.

To be successful with applying math in the workplace, workers need to be able to blend the following:

- Apply and integrate mathematical concepts, procedures, and skills
- Understand the types of practical tasks that require mathematical solutions
- Identify the strategic mathematical process required to solve specified problems
- Identify relevant information or data for use in solving specified problems

Each step in solving a workplace Applied Math problem—from defining the problem through evaluating the results—requires a comprehensive understanding of mathematics.

Another critical difference between the classroom and the workplace is the motivation or purpose for using mathematics. In the classroom, the purpose is often to solve an isolated problem or set of problems. In the workplace, context provides the purpose for doing the work, and a practical need to know the result exists. Finding the best solution in the workplace can be the difference between an effective and efficient operation or one filled with problems, mistakes, and lost opportunities. Mathematical problem solving is often intertwined with other issues, where the mathematical result is linked to business success.

Though people may believe they do not use math often, if at all, in their jobs, mathematics is often hidden in tasks as basic as recording hours on a timesheet, compiling an expense report, counting out change to a customer, or taking a patient's pulse. Mathematics skills and concepts typically used at work include basic operations, spatial reasoning, and converting between units of measurement (Nicol, 2002). In some cases, all that is needed is the ability to total a column of numbers; but, in other cases, the ability to analyze data, to move beyond computation to recursive thinking, multiplicative thinking, abstraction, and spatial visualization is essential (Nicol, 2002).

The modern office worker must also use technology to solve problems. In this context, mathematics is both more concrete and more intuitive. The need for mathematical literacy and quantitative reasoning skills requires workers to be able to work through multiple-step problems and solve three-dimensional problems using two-dimensional data and elementary data analysis (Lappan, 2000).

Levy and Murnane (2004), in their book *The New Division of Labor: How Computers are Creating the Next Job Market*, believe that the increasing use of computers:

> . . . has made people into consumers of mathematics. A clothing manager uses a quantitative model to forecast dress demand. A truck dispatcher uses a mathematical algorithm to design delivery routes. A bakery worker monitors production using digital readouts rather than the smell of bread. Employees of all kinds are expected to use web-based tools to help manage their retirement plans. Each of these tasks involves some aspect of mathematical literacy. In most cases, a computerized tool does the actual calculation, but using the model without understanding the math leaves one vulnerable to potential serious misjudgments (p. 104).

While classroom mathematics may isolate skills and focus on one type of problem at a time, workplace problems may require the application of several different skills to develop a solution. For example, individuals in the workplace may need to know how to select relevant data from a large amount of available information or to recognize that the data are presented in a different metric than the solution requires.

1.3 Applied Math—Assessment Claims

To validate test score interpretations and/or decisions is to review and evaluate the plausibility of the claims made regarding the test and its scores. Kane (2013) maintained that an argument-based approach to validation requires that the score-based claims be clearly articulated along with their associated inferences and assumptions. Validation therefore is a scientific process designed to evaluate the degree to which the analytic and empirical evidence supports the assessment claims along with the inferences and assumptions required to build the connections from examinee task performance to score-based interpretations and uses.

Based on the proposed uses of the Applied Math assessment, the Design Team defined three major claims focusing on workforce development concerns related to worker productivity and success at the individual level, business level, and regional level. Each claim and the underlying assumptions required for it to be plausible is outlined below.

Claim #1: U.S. examinees of high school or workforce age who demonstrate scores that reach at least a given level on the Applied Math assessment are more likely to successfully perform in more and higher levels of U.S. jobs (in the ACT job taxonomy) than examinees whose scores do not reach that level.

Claim #1 Assumptions:

1. The skill of applied mathematics is a component of foundational workplace skills, and it is required for success in a large number of jobs (based on ACT's job profile database).
2. ACT has developed a professionally valid and appropriate definition of the applied mathematics construct.
3. ACT's Applied Math assessment provides reliable and interpretable scores that reflect the construct. ACT's Applied Math assessment elicits observable evidence of the construct.
4. ACT has defined appropriate Applied Math Performance Level Descriptors (PLDs), and ACT has established standards (e.g., cut points) aligned to the PLDs.
5. Cut scores used to delineate each performance level have sufficient classification accuracy.
6. Businesses and employers are able to validly measure worker performance.
7. Scores on the Applied Math assessment are positively related to measures of employee performance, including productivity and turnover rates.
8. Examinees who score well on Applied Math are more likely to receive higher performance ratings and are more likely to have greater job success (as defined as job retention and performance evaluations) than lower scoring examinees.

Claim #2: U.S. companies that hire U.S. examinees of high school or workforce age who demonstrate scores that reach at least a given level on the Applied Math assessment are more likely to achieve greater gains in productivity (for example, measured as increased output per day) from new employees than companies that hire examinees whose scores do not reach that level.

Claim #2 Assumptions:

1. Claim #1 Assumptions 1–7
2. Employees who possess higher foundational workplace skills (as defined by ACT) are more likely to be productive and effective workers (as defined by supervisor evaluations) than employees who possess lower foundational workplace skills.
3. Having more productive workers leads to a business that is more effective and productive.

Claim #3: U.S. companies that hire U.S. examinees of high school or workforce age who demonstrate Applied Math scores that reach at least a given level are more likely to reduce turnover (retain those examinees for at least 6 months) than companies that hire examinees whose scores do not reach that level.

Claim #3 Assumptions:

1. Claim #1 Assumptions 1–7
2. Employees with higher foundational skill levels are less likely to be terminated in the first 6 months of employment than employees with lower foundational skill levels.
3. Employees with higher foundational skill levels are less likely to quit in the first 6 months of employment than employees with lower foundational skill levels.
4. Businesses that utilize scores from the Applied Math assessment as part of their hiring process will tend to experience less turnover than businesses who do not use the Applied Math assessment as part of their hiring process.

The three Applied Math claims address questions around examinee job success, improving worker productivity, and reducing employee turnover rates. Based on the claims, the critical stakeholders and intended test users are employers and hiring managers, state or regional workforce development officials, schools that prepare students to take jobs in the state or region, and examinees who are or will be seeking employment and career advancement.

Included as a part of all three claims are issues related to solving applied mathematical problems as a component of foundational workplace skills, ACT's measure of applied mathematical skills, and ACT's construct definition. These are critical assumptions that must be plausible to support the basis for test score interpretations and uses. (For information and data supporting these underlying assumptions, please refer to Sections 7 and 8.)

1.3 Test Users and Stakeholders

The critical stakeholders are business employers, regional workforce development offices, schools that use the assessment as a measure of workforce readiness, and states or regions committed to developing their workforce. They are the individuals and groups who are invested in finding the right people for the right jobs.

Examinees. Individuals who take the Applied Math assessment are students and workers interested in demonstrating their foundational skill level in order to qualify as career ready, receive specific skill-related training, or qualify for a specific job. The examinee group includes individuals from high school age through adult workers. High school students take the assessment to gain an understanding of their level of career readiness in critical skill areas and/or as a part of state accountability programs. Community college students take the assessment to demonstrate that they possess foundational skills and are ready to move forward for advanced training. College graduates take the assessment to demonstrate their level of career readiness as a means of differentiating themselves from other graduates. Working adults take the assessment to qualify for a job or to demonstrate that they have the foundational skills needed for promotion or advanced training. In short, the examinee group includes high school students and adults who are either seeking employment or looking to advance in their field.

Stakeholders. Stakeholder groups include high schools and local school districts, state departments of education, community colleges, state and local workforce development departments, and employers.

High schools and local school districts administer the WorkKeys assessments in order to evaluate whether their curricular programs are enabling students to become career ready. In doing this, they are also providing their students the opportunity to earn a career ready certificate. State departments of education use the WorkKeys assessments as an accountability measure for evaluating the effectiveness of high schools and school districts in assisting their students to become career ready.

More specifically, the Applied Math assessment provides high schools and school districts with student data regarding the extent to which students have mastered facets of the curriculum associated with solving quantitative problems in order to take an action or make a decision. The application of applied mathematical skills to workplace scenarios differentiates the Applied Math assessment from other standardized assessments of students' mathematics ability. The assessment provides the students the opportunity to demonstrate their quantitative mastery along with specific math skills needed to solve work-related problems.

Community colleges utilize the Applied Math assessment in a variety of ways. Many community colleges use it as part of the process for determining acceptance into Career and Technical Education programs. Other community colleges use the assessment for program evaluation. Additionally, some community colleges use it as a means of assisting their graduates in obtaining employment.

State and local workforce development offices utilize the assessment as a means of assisting unemployed or underemployed individuals in finding employment or better opportunities. The assessment provides a means for the workforce development office personnel to better understand the skill levels of individuals and to provide better guidance and assistance to them in finding employment.

Employers may use the Applied Math assessment, when coupled with a job profile analysis, to assist them in screening job applicants and finding sufficiently-qualified employees. A WorkKeys Job Profile allows the employer to understand the level of skill needed by a newly hired employee to successfully meet job expectations. Following the profile process, the employer may have job applicants take the assessment and then use their test scores as an additional piece of information to evaluate applicants.

1.4 Alignment to ACT's Holistic Framework

Building on research conducted over the last 50 years, ACT has developed its Holistic Framework (Camara, O'Connor, Mattern, & Hanson, 2015), which provides a more complete description of college and career readiness. The framework is organized into four broad domains: core academic skills, cross-cutting capabilities, behavioral skills, and education and career navigation skills.

1. Core academic skills include the domain-specific knowledge and skills necessary to perform essential tasks in the core academic content areas of English language arts, mathematics, and science.
2. Cross-cutting capabilities include the general knowledge and skills necessary to perform essential tasks across academic content areas. This includes technology and information literacy, collaborative problem solving, thinking and metacognition, and studying and learning.
3. Behavioral skills include interpersonal, self-regulatory, and task-related behaviors important for adaptation to and successful performance in education and workplace settings.
4. Education and career navigation skills include the personal characteristics, processes, and knowledge that influence individuals as they navigate their educational and career paths (e.g., make informed, personally relevant decisions; develop actionable, achievable plans).

The Applied Math assessment aligns primarily with the first broad domain of ACT's Holistic Framework, which includes domain-specific knowledge and skills necessary for performing essential tasks. The skills fall into six major categories in the mathematics content area: basic operations with numbers, fractions, percentages/ratios/proportions, unit conversions, geometric measurement, and applied math reasoning.

The Applied Math assessment uses authentic work-related problems and scenarios in order to determine an examinee's level of proficiency in solving applied mathematical and quantitative problems. The skill of being able to correctly set up applied mathematical problems, find solutions, and identify mathematical errors are skills necessary in both academic and workplace settings. As such these skills are the focus of the Applied Math assessment and align this assessment to the skills defined in the Holistic Framework of education and work readiness.

Section 2: Test Development

WorkKeys Applied Math is designed to assess the extent to which individuals can use mathematical skills needed in workplaces. The ability to think through problems in order to find and evaluate solutions is critical for workplace success (Australian Association of Mathematics Teachers, 2014; Smith, 1999). The Applied Math assessment measures skills that individuals use when they apply mathematical reasoning and problem-solving to work-related problems.

Through a review of the pertinent empirical and professional literature and consultation with external SMEs, the Design Team determined that the Applied Math assessment measures the construct through a combination of the test item characteristics and the mathematics skill elicited by the item. For example, a Level 5 item must meet the content criteria (identified in Table 2.1) and assess a mathematics skill identified as a Level 5 skill (see Tables 2.2 through 2.7). Both the item characteristics and the mathematics skills are aligned to a level of difficulty for the assessment.

2.1 Applied Math—Expanding the Construct based on Review

The Design Team carefully reviewed information and research assessing the uses of workplace applied mathematical skills. This review and consultation with the external panel of SME revealed that technology (particularly spreadsheets, calculators, and scanning devices) removed many of the computational demands. Despite these advanced tools, employees still needed mathematical and quantitative reasoning skills. For example, employees utilize spreadsheets to do calculations, but they must be capable of troubleshooting and finding errors in cells that are automatically calculated. Furthermore, in production situations, employees need to be able to understand and interpret measures of central tendency, spread, and tolerances, particularly as they relate to quality control. Given the evaluation and feedback, the following skills were expanded in the revised Applied Math assessment.

1. Troubleshooting was expanded to include identifying whether an error occurred. In these cases, examinees must identify where values are incorrect.
2. Basic statistical concepts were expanded beyond calculating means and medians to include calculating tolerances, as well as interpreting measures of variance or spread. Examinees might be asked to interpret or make a decision based on statistical values, but they are not required to calculate the values. Interpreting these values are considered within the construct of the Applied Math assessment; calculating these values are considered outside of the construct.
3. Identifying the correct equation was added to assess examinees' skill in creating and comprehending equations used to produce automated calculations.

2.2 Applied Math—Item Stem Characteristics

The Design Team found that the successful application of mathematics in work-related situations incorporates problem solving and integrates mathematical and quantitative reasoning skills (Australian Association of Mathematics Teachers, 2014; Smith, 1999). While the proliferation of spreadsheets and calculators in the workplace has reduced the need for computational skills, employees still need to be able to apply quantitative reasoning skills to solve complex problems. Item levels are determined by the situational and problem solving complexity along with the mathematical skill and reasoning required.

Because the Applied Math assessment presents realistic workplace problems, each item is defined, in part, by its context. To assist in creating realistic workplace problems, each test item is presented in the context of money, time, measurement, or quantity.

ACT defines Applied Math items as having varying degrees of complexity. The complexity of each item is determined by the following characteristics:

- Presentation of quantitative information
- Amount of language that must be understood to translate the item into a mathematics problem
- Inclusion of extraneous information
- Inclusion of a graph
- Number of steps required for setting up the problem, making calculations, and solving for unknowns

The Design Team developed Table 2.1 to provide guidelines describing the characteristics for each level.

Table 2.1: Item Characteristics by Level

Item Stem Characteristics	Level 3	Level 4	Level 5	Level 6	Level 7
Presentation of Quantitative Information	Presented in logical order	May not be in logical order	May not be in logical order	May not be in logical order	May have incomplete information or require an assumption
Amount of Language to Translate to Math Expression	Minimal	Some	Some	Considerable translation	May have unusual format
Extraneous Information	None	May have some extraneous information	May have some extraneous information	May have some extraneous information	May have some extraneous information
Contains Simple Graph	No	May be included	May be included	May be included	May be included
Set up/ Planning	Minimum set-up	Some set-up required	May require complicated set-up	May require complicated set-up	May require complicated set-up
Calculations	One operation	One or two operations	May have several operations	May have several operations	May have several operations
Solving for Unknowns	Solve for one unknown	Solve for one or two unknowns	May solve for one unknown and then use to solve the problem to answer the question	May solve for one unknown and then use to solve the problem to answer the question	May solve for one unknown and then use to solve the problem to answer the question

Using this table: The table is intended as a guide describing the general characteristics of the item for each given Level.

2.3 Applied Math—Skill Definitions

The Applied Math assessment strives to measure the most relevant and consequential foundational mathematical skills that are widely used in the workplace. To determine these skills, the Design Team drew upon information from the ACT JobPro® Database, professional literature, and feedback from external SMEs.

The Applied Math assessment construct was defined through six critical skills. Each of the six skills was subdivided into subskills. The skill and subskill definitions collectively constitute the workplace Applied Math assessment construct. Tables 2.2 through 2.7 provide the subskills that constitute each Applied Math skill.

Table 2.2: Skill 1.0—Basic Operations with Numbers Including Decimals

1.0	Basic Operations with Numbers Including Decimals
	Subskills:
1.1	Add positive numbers
1.2	Add with negative number(s)
1.2.1	Add more than four numbers, some of which may be negative
1.2.2	Add two negative numbers
1.3	Subtract positive numbers
1.3.1	Subtract positive numbers where the result is positive
1.3.2	Subtract positive numbers where the result is negative
1.4	Subtract with negative number(s)
1.4.1	Positive minus negative
1.4.2	Negative minus positive
1.4.3	Negative minus negative
1.5	Multiply positive numbers
1.6	Divide positive numbers (result could be a fraction)
1.7	Two or more basic operations

Table 2.3: Skill 2.0—Fractions

2.0	Fractions
	Subskills:
2.1	Add/Subtract fractions
2.1.1	Add/Subtract fractions (limited to halves and fourths). No more than two fractions
2.1.2	Add/Subtract fractions that share a common denominator (such as 1/8 + 3/8 + 7/8)
2.1.3	Add/Subtract fractions with unlike denominators
2.2	Multiply fractions
2.2.1	Multiply fractions (none are mixed numbers)
2.2.2	Multiply a mixed number (such as 12 1/8) by a whole number or a decimal
2.2.3	Multiply more than 1 mixed number
2.3	Divide fractions
2.4	Change between fractions and decimals

Table 2.4: Skill 3.0—Percentages/Ratios/Proportions

3.0	Percentages/Ratios/Proportions
	Subskills:
3.1	Convert between decimals and percentages
3.2	Calculate a given percentage of a given number; (e.g., what is 4% of 10? Tax, commission, discount, markup, raise)
3.3	Calculate the percentage one number is of another. (e.g., 6 is what percentage of 15?)
3.4	Calculate percent change
3.5	Calculate reverse percent (e.g., you have discounted a coat by 15% and now the sales price is $30; what was the original price?)
3.6	Set up and/or manipulate Simple Ratio/Proportions/Rates
3.6.1	Figure out simple ratios
3.6.2	Figure out simple proportions
3.6.3	Figure out simple rates (such as 10 mph)
3.7	Set up and/or manipulate ratios, rates, or proportions (at least one of the quantities related is a fraction)
3.8	Rates, production rates, rate x time (e.g., 15 cups over 40 mins = x cups per minute; at 59 units per hour, how many made in 8 hours?)

Table 2.5: Skill 4.0—Unit Conversions

4.0	Unit Conversions
	Subskills:
4.1	Convert between familiar units (between: hours and minutes, dollars and cents)
4.2	Convert where the conversion factor is given in the problem
4.3	Convert where you must select the conversion factor (e.g., from the formula sheet)
4.4	Two or more step conversions (e.g., inches to feet to yards, kilometers to meters to feet)
4.5	Two or more separate conversions (e.g., problem that has minutes to hours and pounds to ounces)
4.6	Operations with mixed units (e.g., add 6 feet 4 inches and 3 feet 8 inches, 3.5 hours + 4 hours 30 minutes, etc.)
4.7	Convert the unit of measurement using fractions, mixed numbers, decimals, or percentages

Table 2.6: Skill 5.0—Geometric Measurement

5.0	Geometric Measurement
	Subskills:
5.1	Calculate perimeter or circumference
5.2	Calculate area
5.2.1	Find the area of one rectangle with dimensions given
5.2.2	Find the area of other polygons with dimensions given
5.2.3	Find the area of a circle given radius or diameter
5.2.4	Find the area of multiple shapes
5.2.5	Find the area of a composite shape
5.2.6	Find the area when it may be necessary to rearrange the formula, convert units of measurement in the calculations, or use the result in further calculations
5.3	Calculate volume
5.3.1	Calculate volume of a rectangular solid
5.3.2	Calculate volume of spheres, cylinders, and cones
5.3.3	Find the volume when it may be necessary to rearrange the formula, convert units of measurement in the calculations, or use the result in further calculations

Table 2.7: Skill 6.0—Applied Math Reasoning

6.0	Applied Math Reasoning
	Subskills:
6.1	Troubleshooting
6.1.1	Identify where a mistake occurred (e.g., in the spreadsheet, identify the row where the problem occurred)
6.1.2	Identify the reason for the mistake
6.2	Best Deal
6.2.1	Find the best deal using one- or two-step calculation that meets the stated conditions
6.2.2	Find the best deal from a group and then do something with the answer
6.2.3	Determine the better economic value of several alternatives by using graphics, or determining the percentage difference, or by determining unit cost
6.3	Basic Statistical Concepts
6.3.1	Calculate the average (mean)
6.3.2	Calculate the weighted average
6.3.3	Interpret measures of central tendency
6.3.4	Interpret measures of spread and tolerances
6.4	Identify the Correct Equation

2.4 Applied Math—Performance Level Descriptors (PLDs)

Individuals taking the assessment earn a scale score and a level score. Scale scores range from 65 to 90. The scale scores are transformed to level scores ranging from Level 3 to Level 7. Most examinees focus on their level scores because they have interpretability related to job skills. Consistent with the other WorkKeys NCRC assessments, Level 3 is defined as the lowest level at which an employer would be willing to hire and pay an employee to perform those skills in a job requiring applied mathematics. (Examinees who demonstrate applied mathematics proficiency below Level 3 do not receive a level score.) Level 7 is defined as the highest skill level that an employee could be expected to hold without specialized formal training.

Applied Mathematics score levels are interpreted as a progression in that a test taker who holds skills at a specific level will be able to do the skills defined for each lower level. For example, a test taker who scores at Level 5 not only possesses the skills defined as Level 5 skills, but he or she also possesses the skills defined at Levels 3 and 4.

The following section identifies PLDs for examinees who earn scores at each level.

Applied Math Level 3

Level 3 problems can easily be translated from a word problem to a math equation requiring a single type of math operation. All the needed information is presented in logical order and there is no extra information given. When test takers use Level 3 Applied Math skills, they are able to:

- Solve problems that require one type of mathematical operation. They add or subtract either positive or negative numbers (such as 10 or -2). They multiply or divide using only positive numbers (such as 10).
- Convert a familiar fraction (such as ½ or ¼ to a decimal) and convert from a decimal to a common fraction; OR convert between decimals to percentages (such as 0.75 to 75%).
- Convert between familiar units of money and time (such as one hour equals 60 minutes or ½ of a dollar equals $0.50).
- Add the prices of several products together to find the total, and calculate the correct change for a customer.

Applied Math Level 4

In Level 4 problems, tasks may present information out of order and may include extra, unnecessary information. One or two operations may be needed to solve the problem. A chart, diagram, or graph may be included. When test takers use Level 4 Applied Math skills, they use the skills described at Level 3, and they also are able to:

- Solve problems that require one or two mathematical operations. They can add, subtract, or multiply using positive or negative numbers (such as 10 or -2), and they can divide positive numbers (such as 10).
- Calculate the average or mean of a set of numbers (such as $\frac{(10+11+12)}{3}$). For this, they may use whole numbers and decimals.
- Figure out simple ratios (such as ¾), simple proportions (such as 10/100 cases), or rates (such as 10 mph).
- Add commonly known fractions, decimals, or percentages (such as ½, 0.75, or 25%).
- Add or subtract fractions with a common denominator (such as ¼ + ¾ + ¼).
- Multiply a mixed number (such as 12 1/8) by a whole number or a decimal.
- Put the information in the right order before they perform calculations.

Applied Math Level 5

In Level 5 problems, the information may not be presented in logical order; the item may contain extraneous information; it may contain a graph or diagram; and the mathematical set-up may be complicated. In solving, the test taker may need to perform multiple operations. (For example, at this level, examinees may complete an order form by totaling an order and then calculating sales tax.) When test takers use Level 5 Applied Math skills, they use the skills described at Levels 3 and 4, and they also are able to:

- Decide what information, calculations, or unit conversions to use to find the answer to a problem.
- Add and subtract fractions with unlike denominators (such as ½ - ¼).
- Convert units within or between systems of measurement (e.g., time, measurement, and quantity) where the conversion factor is given either in the problem or in the formula sheet.
- Solve problems that require mathematical operations using mixed units (such as adding 6 feet and 4 inches to 3 feet and 10 inches, or subtracting 4 hours and 30 minutes from 3.5 hours).
- Identify the best deal using one- or two-step calculations that meet the stated conditions.
- Calculate the perimeter or circumference of a basic shape or calculate the area of a basic shape
- Calculate a given percentage of a given number and then use that percentage to find the solution to a problem (e.g., find the percentage and then use it to find the discount, markup, or tax).
- Identify where a mistake occurred in a calculation (such as identifying the row in a spreadsheet where a problem occurred).

Applied Math Level 6

Level 6 problems may require considerable translation from verbal form to mathematical expression. They generally require considerable setup and involve multiple-step calculations. When test takers use Level 6 Applied Mathematics skills, they use the skills described at Levels 3, 4, and 5, and they also are able to:

- Use fractions with unlike denominators and calculate reverse percentages.
- Convert units within or between systems of measurement (e.g., time, measurement, and quantity) where multiple-step conversions are required and the formulas are provided such as converting from kilometers to meters to feet.
- Identify why a mistake occurred in a solution.
- Find the best deal from a group of solutions and then use the result for another calculation.
- Find the area of basic shapes when it may be necessary to rearrange a formula, convert units of measurement in the calculations, or use the result in further calculations.
- Calculate the volume of rectangular solids (e.g., cubes)
- Calculate rates, productions rates, rate by time (such as, production rate is 59 cups produced per hour, how many will be produced in an 8 hour shift).
- Identify the correct equation for solving a problem.

Applied Math Level 7

Level 7 problems may be presented in an unusual format and information presented may be incomplete or require the test taker to make an assumption. Problems often involve multiple steps of logic and calculation. When test takers use Level 7 Applied Math skills, they use the skills described at Levels 3, 4, 5, and 6, and they also are able to:

- Solve problems that include ratios, rates, or proportions where at least one of the quantities is a fraction.
- Identify the reason for a mistake.
- Convert between units of measurement using fractions, mixed numbers, decimals, and percentages.
- Calculate volumes of spheres, cylinders, or cones.
- Calculate the volume when it may be necessary to rearrange the formula, convert units of measurement in calculations, or use the result in further calculations.
- Set up and manipulate ratios, rates, or proportions where at least one of the quantities is a fraction.
- Determine the better economic value of several alternatives by using graphics, or determining the percentage difference, or by determining unit cost.
- Apply basic statistical concepts. For example, calculate the weighted mean, interpret measures of central tendency, or interpret measure of spread and tolerance.

2.5 Designing Items to Elicit Evidence of Applied Math

Applied Math uses multiple-choice items to measure examinees' proficiency in various mathematical skills necessary for workplace success. The mathematical skills measured by the assessment were defined by the Design Team and confirmed by external SMEs with backgrounds in business, industry, and education. To properly elicit evidence of the skills in the Applied Mathematics domain, ACT follows an item-design model aligned with both evidence-centered assessment design (Mislevy, Steinberg, & Almond, 1999) and the *Standards for Educational and Psychological Testing* (American Educational Research Association (AERA), American Psychological Association (APA), & National Council for Measurement in Education (NCME), 2014).

2.5.1 Item Writing

Item writers qualify to write for the Applied Math assessment by completing item-writing training modules. The modules cover numerous aspects of developing quality multiple-choice items including creating word problems that elicit evidence of the skill the item measures, writing effective distractors, employing realistic workplace contexts, and avoiding common item-writing errors. Once an item writer has successfully completed all required training modules, he or she is given an item-writing assignment that details the number of items to be developed at specific levels and for specific subskills. The assignment may also include other item specifications such as Career Cluster alignment, the required level of stem complexity, the presence or absence of particular data displays, or other item-defining characteristics. Below are additional requirements universal to all Applied Math items:

- The context must be work-related and realistic, and the mathematics should be authentic to the work presented in the item.
- Prices, rates, and procedures in the item should be authentic and realistic for the next few years. Moreover, the source of the information regarding the prices, rates, and procedures should be documented.
- The items should avoid overlap with the Graphic Literacy assessment. While graphics are allowed in an item, the mathematical skill must be the emphasis of the item rather than reading and interpreting the graphic.

2.5.2 Item Review

After items have been developed, edited, and tentatively finalized by the Content Assessment team, they are submitted to external consultants with backgrounds in workplace math assessment for content and fairness review.

In the content review, they evaluate

- whether the item is appropriately aligned to the construct
- whether the context and the solution method are workplace authentic and relevant
- whether there is one, and only one, correct response

Reviewers evaluate items and passages for fairness and cultural bias by considering how members of different demographic groups would respond to the item. (ACT asks the item reviewer to evaluate the item from the perspective of men and women examinees, and from the perspective of African-American, Hispanic-American, and Asian-American examinees.) The reviewer is asked to comment on whether there is anything within the item that any group might find offensive. Also, the reviewer is asked to evaluate if each demographic group has equal access to, and opportunity to learn, the information and skills assessed.

Item reviewers include representation from various facets of our multicultural society. Reviewers are recruited to achieve a balance of gender and a wide representation of ethnicity, geographic region, and urbanity. All test reviewers are recruited in part for their alertness to cultural diversity factors and for their sensitivity to issues of cultural diversity and fairness. Reviewers' performance is regularly evaluated by ACT staff.

For both the content and fairness reviews, item reviewers complete questionnaires either approving the item as written or identifying specific concerns. The content team gathers the information from the reviewers and determines how to appropriately address any concerns. Items are not classified as ready for pretesting until all relevant issues are resolved.

2.5.3 Item Pretesting

All Applied Math items are pretested before they become operational. Newly developed or recently revised items are embedded in current forms of the Applied Math assessment. As a result, examinees respond to the pretest items as a part of their responses to the operational assessment.

ACT conducts statistical analyses to determine if each pretest item meets required statistical criteria. ACT analyzes the items using both classical and item response theory (IRT) statistics to evaluate their psychometric properties, including overall difficulty and discrimination. If an item fails to meet the statistical criteria, the Applied Math content team reviews it and considers whether it should be edited or removed from the pool. When an item is edited, it receives a new item identifier and is pretested a second time.

To ensure item fairness, ACT also compares item difficulty values based on group membership (item analysis is conducted comparing difficulty levels by gender and ethnic status) and performs Differential Item Functioning (DIF) evaluations (Holland & Wainer, 1993). Items that are flagged through the DIF evaluations are sent to the Applied Math content team for review. The content team determines whether the flagged item should remain as it currently is, be revised and returned to pretesting, or be removed from the pool.

Section 3: Test Specifications

An assessment's specifications are developed by first determining the assessment's claims and score interpretations, followed by articulating the set of behaviors that need to be elicited through the test content to provide evidence to support the claims. In articulating the set of behaviors, the team evaluates the degree to which examinee responses to the item content provide support for the assessment's claims and score interpretations. Item and test content must elicit examinee behaviors that are aligned to the construct and that provide evidence supporting score interpretations (Kane, 2013; Messick, 1989).

The Applied Math Design Team utilized a variety of reputable source materials to identify relevant content that constitutes a measure of workplace applied mathematics. Over the past 25 years, through its job profiling services, ACT has gathered information related to workplace quantitative problems, tasks involving mathematics, and mathematical skills from the manufacturing, health care, construction, transportation, financial, and sales sectors. The Applied Math team reviewed these findings and used the information to determine what types of problems should be included and which skills were most frequently required. To further support content-related decisions, the team reviewed the workplace professional competency models (National Network of Business and Industry Associations (NNBIA), 2014). Lastly, the team consulted with a group of external SMEs to obtain their perspective on workplace applied mathematics skills.

3.1 Content Relevance and Representativeness

Test specifications must be carefully defined to ensure that the assessment tasks are construct relevant and representative of the domain purported to be measured (Messick, 1989; Mislevy, Steinberg, & Almond, 1999). In the context of Applied Math, construct relevance requires not only that the examinee demonstrate the ability to solve mathematical problems, but that he or she also demonstrates the ability to use the tools commonly found in the workplace for solving quantitative problems. Because WorkKeys assessments are designed to measure skills that are widely applicable to a large number of jobs, construct representativeness refers to a range of problems and the various mathematical skills needed in the workplace. To illustrate, the context of the mathematical problems must be applicable to the full range of job sectors, from manufacturing to construction to office work and beyond. The problems must also represent appropriate ranges of difficulty, from basic operations, to more complicated multi-step problems, to the use of quantitative reasoning.

A second purpose of the test specifications involves the development of alternate forms. The size of the WorkKeys test population combined with the need for security and fairness necessitates the construction of alternate forms of the Applied Math assessment. In developing alternate forms, ACT requires that all forms must meet Lord's (1980) equity property. Lord's equity property states, from the test taker's perspective, it must be a matter of score indifference whether he or she is administered Form A or Form B of an assessment. To achieve alternate forms that meet the equity property, the content representativeness of each form must be identical (Kolen & Brennan, 2004).

By carefully defining the content specifications, ACT accomplishes two critical assessment goals:

1. Content is construct relevant and representative.
2. Content representation is identical across alternate forms.

3.2 Applied Math—Test Blueprint

ACT developed detailed blueprints defining the content attributes of each test item. The content specifications were developed by clearly specifying the attributes of the types of problems that workers solve. Using this information, the team identified six primary applied mathematical skills. Analyzing the data further, the team defined the subskills that existed within each of the primary skills. The team using the job profiling data weighted the criticality and frequency of use of each subskill (Allen & Yen, 2002). Doing this resulted in some subskills being removed. The weightings were then reviewed by the external SMEs, and based on their feedback, the team made final adjustments to the blueprint. Lastly, the team evaluated the problem context and set up a table recommending the problem context distribution.

The workplace Applied Math construct was based on three critical facets:

- Applied Mathematical Complexity Level
- Applied Mathematical Skills
- Applied Mathematical Problem Context

The Applied Mathematical Complexity Level was divided into five levels and defined by the presentation of quantitative information, amount of language used to translate to math expression, amount of extraneous information, whether it contains a graphic, the planning and mathematical set-up, and the number of unknowns (see Table 2.1).

Applied mathematical skills were divided into six primary skills. Through analyzing the professional literature on applied mathematics and data from ACT's job profiling, ACT learned that workplace applied mathematics is conducted using tools (e.g., calculators and spreadsheets). Ensuring that workers can effectively use these tools to apply their mathematical skills and find the correct solution thus becomes a critical component of the assessment.

Four critical contexts were identified as relevant to workplace applied mathematics: quantity, money, time, and measurement. The overwhelming majority of foundational applied mathematics workplace tasks involved one of these four contexts.

Tables 3.1 and 3.2 present a summary of the Applied Math test specifications. The test specifications provide a blueprint for form development and also represent the relative importance of the applied mathematics skills in the workplace.

Table 3.1: Applied Math Skills Item Distribution by Level

	Number per Level					
Domain	Level 3	Level 4	Level 5	Level 6	Level 7	Total
1.0 Basic Operations with Numbers Including Decimals	4	2	0	0	0	6
2.0 Fractions	1	2	1	0	0	4
3.0 Percentages/Ratios/Proportions	0	1	1	2	1	5
4.0 Unit Conversions	1	0	2	1	1	5
5.0 Geometric Measurement	0	0	1	1	1	3
6.0 Applied Mathematics Reasoning	0	1	2	2	3	8
Total Item Count	6	6	7	6	6	31

Table 3.2: Number of Items per Level for Applied Math Applications

	Number per Level					
Application	Level 3	Level 4	Level 5	Level 6	Level 7	Total
Quantity (QUA)	0–4	0–4	0–4	0–4	0–4	4–9
Money (MON)	0–4	0–4	0–4	0–4	0–4	4–9
Time (TIM)	0–4	0–4	0–4	0–4	0–4	4–9
Measurement (MEA)	0–4	0–4	0–4	0–4	0–4	4–9
Total	6	6	7	6	6	31

Each form of the Applied Math assessment is built to conform to the test specifications defined in Tables 3.1 and 3.2. ACT's test development and psychometric staff members thoroughly review each form to ensure that it meets the content specifications and that each form is parallel to all other Applied Math forms.

Section 4: Test Administration

The *ACT WorkKeys Administration Manual—Paper Testing* and *ACT WorkKeys Administration Manual—Online Testing* provide direction in the administration of the WorkKeys assessments including timing instructions. It is important that all staff involved in the administration of WorkKeys assessments follow the instructions as provided by ACT to appropriately measure the skills and abilities of the individuals completing the assessments.

4.1 Standard Test Administrative Procedures

Included in the two manuals are detailed directions for securing materials and administering the assessments in a standardized manner. The following actions violate ACT policies and procedures for delivering WorkKeys assessments:

- accessing or obtaining a test booklet or test questions prior to the test for any reason (An exception is provided for American Sign Language and Signing Exact English interpreters assisting examinees)
- photocopying, making an electronic copy, or keeping a personal copy of the test or of any test items
- taking notes about test questions or any paraphrase of test questions to aid in preparing examinees for testing
- aiding or assisting an examinee with a response or answer to a secure test item, including providing formulas
- rephrasing test questions for examinees
- creating an answer key or “crib sheet” of answers to test questions
- editing or changing examinee answers after completion of the test, with or without the examinee’s permission
- allowing examinees to test in an unsupervised setting
- leaving test materials in an unsecured place or unattended
- failing to properly report and document incidents of prohibited behavior involving examinees, staff, or others
- allowing examinees to test longer than the permitted time
- failing to return and account for all testing materials after the testing session has ended

4.2 Test Administration Personnel

ACT identifies a Test Center Coordinator to select and reserve appropriate rooms required for testing, select and train qualified personnel to administer the assessments, order and ensure the security of all test materials, and coordinate all activities on test days. The Test Center Coordinator should have a back-up coordinator who is responsible for carrying out activities should the Test Coordinator not be able to do so.

ACT provides copies of the administrative manuals, which every staff member is expected to read, understand, and follow. The manual is proprietary information and is copyrighted by ACT. It is to be used only for the purpose of administering the ACT WorkKeys assessments and is not to be copied or shared for any other purpose.

The Test Center Coordinator trains all staff members in administrative and security procedures. Each testing staff member is to be provided with a complete copy of the administrative manual before the training session. The Test Center Coordinator works with the testing staff to ensure that the WorkKeys assessments are administered in a standardized manner in rooms that meet WorkKeys requirements.

Section 5: Accessibility

The Applied Math assessment uses a variety of levels of accessibility supports including default embedded tools, open access tools, and full accommodations to allow all examinees, including those with disabilities, to participate in testing.

5.1 Assessment Support System

The Applied Math assessment contains a system of supports for effective communication that spans a continuum from the most simple, common accessibility tools used by everyone, to the most intensive accessibility supports that require the user to have specific qualifications and expertise. The levels of this continuum provide for an assessment system that meets the needs of all populations tested and provides a fair communication and performance pathway for all learners.

“Accessibility is the degree to which the items or tasks on a test enable as many test takers as possible to demonstrate their standing on the target construct without being impeded by characteristics of the item that are irrelevant to the construct being measured.” (AERA et al., 2014, p. 215). The Applied Math assessment support continuum is an inclusive concept that recognizes that the need for personalized communication supports is not restricted to any one group of examinees. It describes needs we all have, regardless of whether or not we have an official diagnostic label. It encompasses the needs of the entire testing population, including those with disabilities, those who are English Learners, as well as all the rest who have no diagnostic label at all. All of these individuals have a shared need to be able to fairly and effectively communicate what they know and can do when they take a test.

To provide a fair performance pathway for all learners, including populations with diverse needs, the development of the Applied Math assessment followed a theory of action known as Access by Design (Fedorchak, 2013), which incorporates elements of Universal Design for Learning (UDL) described by the Center for Applied Special Technologies (CAST, 2011), and Evidence Centered Design (Mislevy, Almond, & Lukas, 2004; Mislevy & Haertel, 2006).

In September 2015, in anticipation of the development of this assessment, a week-long workshop related to accessible test development was held with leadership and content developers of WorkKeys NCRC assessments. The topic of the workshop focused on methods of mapping the characteristics and accessibility needs of learner populations to the content models intended to be measured by the NCRC assessments. During this training, accessibility consultants provided feedback with respect to accessible definitions of constructs to be tested and a plan was established for ongoing accessibility consultation and advisement during test development.

The Applied Math assessment accessibility supports are structured along a continuum of increasingly intensive supports designed to meet the needs of all participating learner populations. Three levels of accessibility supports are offered: (a) Embedded Tools, (b) Open Access Tools, and (c) Accommodations. Embedded tools are commonly used by many people, available to all examinees, and do not need to be requested in advance. Open Access Tools are used by fewer people, are also available to anyone, but their use must be identified and planned for locally in advance. Accommodation-level supports and tools are the most intensive levels of support. Accommodations are available to those who are qualified to use them. Currently, certain supports are only available with the paper form of the test.

Beginning in 2018, several new accessibility supports will be added to the Applied Math assessment for both paper and online forms. These additions will fill out the planned continuum of accessibility supports and will provide many options for unique personalization of experience for each examinee.

5.2 Test Administration and Accessibility Levels of Support

Over the last decade, the educational assessment profession has come to understand that all examinees have tools they need and use every day to engage in the classroom and to communicate effectively what they have learned and can do. There are different levels of support that examinees may need in order to demonstrate what they know and can do on academic tests. The Applied Math assessment makes several possible levels of support available. All these levels of support taken together are called accessibility supports. These accessibility supports:

- allow all examinees to gain access to effective means of communication that in turn allow them to demonstrate what they know without providing an advantage over other examinees
- enable effective and appropriate engagement, interaction, and communication of examinee knowledge and skills
- honor and measure academic content as the test developers originally intended
- remove unnecessary barriers to examinees demonstrating the content, knowledge, and skills being measured on the Applied Math assessment

In short, accessibility supports do nothing for the examinee academically that he or she should be doing independently; they just make interaction and communication possible and fair for each examinee.

The Applied Math assessment accessibility system defines four levels of support that range from minor support (default embedded system tools) to extreme support (modifications). Figure 5.1 shows the architectural structure of WorkKeys assessments accessibility supports. The width of the triangle shows the proportionate number of students who use that set of accessibility tools.

The Applied Math assessment permits the use of only those accessibility supports that validly preserve the skills and knowledge that the assessment claims to measure, while removing needless, construct-irrelevant barriers to examinee performance. The four levels of support in the assessment accessibility system represent a continuum of supports, from least intensive to most intensive, and assumes all users have communication needs that fall somewhere on this continuum. The continuum of supports permitted in the Applied Math assessment results in every examinee having a personalized performance opportunity.

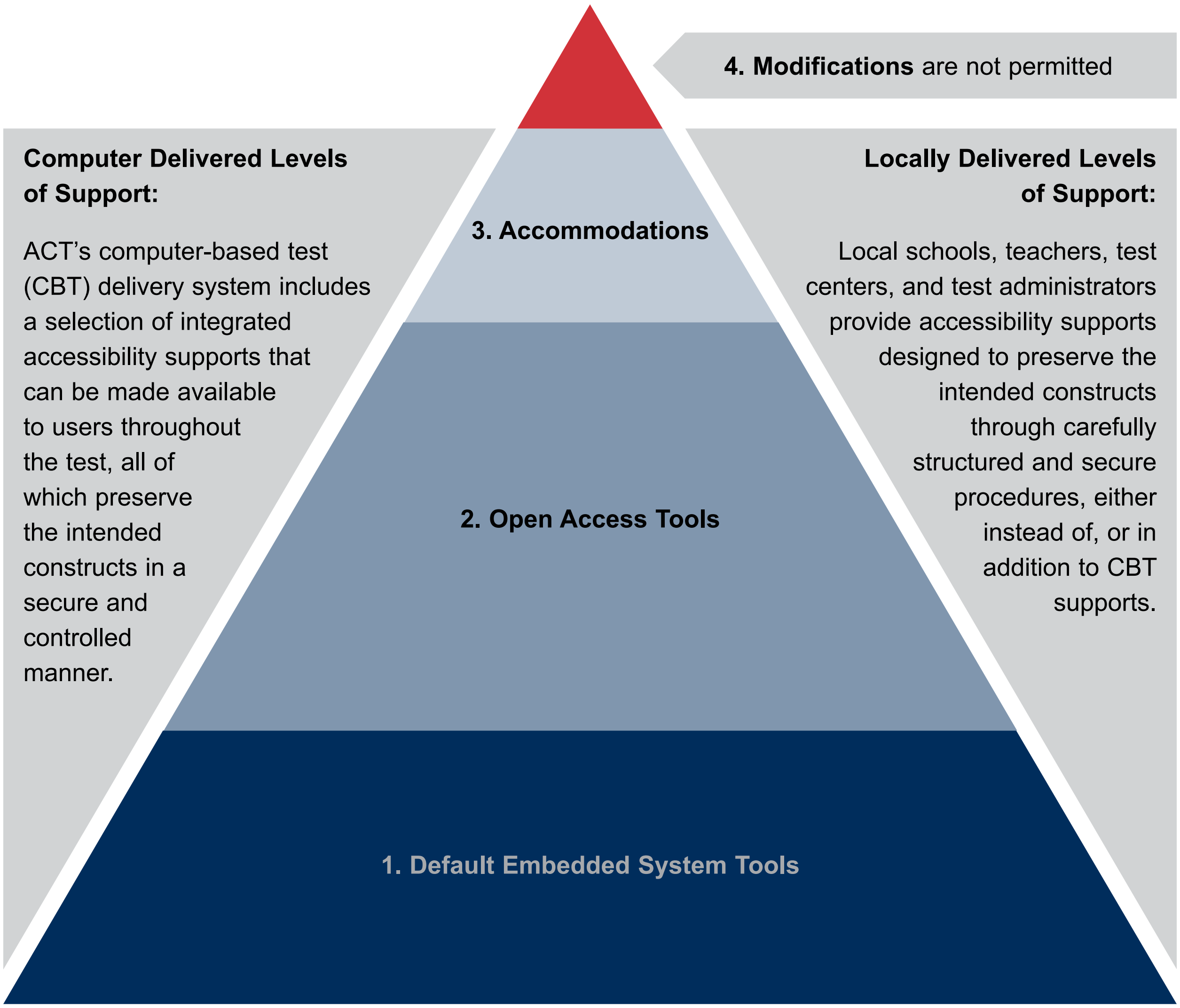

Figure 5.1 Architectural Structure of Accessibility Supports

Support Level 1: Default Embedded System Tools

The first level of supports is called the Default Embedded System Tools. (See the first level of the pyramid in Figure 5.1.) These tools are automatically available to a default user whose accessibility needs are sufficiently met through the basic test administration experience.

Default embedded system tools meet the common, routine accessibility needs of the most typical test takers. All examinees are provided these tools as appropriate, even examinees who have no documented support plan. Default embedded system tools include but are not limited to the following examples in online and paper tests:

- Magnifier Tool (online and paper)
- Browser Zoom Magnification (online)
- Answer Eliminator (online and paper)

- Test Directions Available on Demand (online and paper)
- Highlighter (online and paper)
- Keyboard Navigation (online)
- Mark Item for Review (online and paper)

Default embedded system tools are common supports made available to all users upon launch or start of the test; they are the accessibility tools that nearly everyone uses routinely and assumes will be made available although we seldom think of them in this way. These tools are either embedded in the basic computer test delivery platform, or locally provided as needed. No advance request is needed for these supports.

Support Level 2: Open Access Tools

Open Access tools (see the second level of the pyramid in Figure 5.1) are available to all users, but must be identified in advance, planned for, and then selected from the menu inside the test to be activated (online), or else provided locally.

Many examinees' unique sensory and communication accessibility needs are predictable and can be met through a set of accessibility features designed into the underlying structure and delivery format of test items. Rather than overwhelm the user with all the possible tools, Open Access tools provide just the tools needed by individual users, allowing true personalization of the test experience.

Open Access tools are slightly more intensive than default embedded system tools but can be delivered in a fully standardized manner that is valid, appropriate, and personalized to the specific access needs identified for an individual examinee. Some of these require the use of tool-specific administration procedures. In the Applied Math assessment, Open Access tools include, but are not limited to the following examples:

- Color Contrast (online and paper)
- Line Reader (online and paper)
- Translated Verbal: Directions Only (online and paper) locally provided
- Signed Exact English (SEE) for Directions Only (paper)—locally provided
- Answer Masking (online and paper)
- Dictate Responses (online and paper)
- Respond in Test Booklet or on separate paper (online and paper)
- Audio Indicator of Time Remaining (online and paper)
- Individual Administration (online and paper)
- Special Seating/Grouping (online and paper)

Open Access tools should be chosen carefully and specifically to prevent the examinee from becoming overwhelmed or distracted during testing. Room supervisors must follow required procedures. Prior to the testing experience, examinees need to have an opportunity to practice and become familiar and comfortable using these types of tools as well as using them in combination with other tools.

Support Level 3: Accommodations

Accommodations are high-level accessibility tools needed by relatively few examinees. (See the third level of the pyramid in Figure 5.1.) The Applied Math assessment system requires accommodation-level supports to be requested by education personnel on behalf of an examinee. The accommodations must be identified in advance, planned, and selected from the menu inside the test to activate them (online), or else provided locally. Accommodations often require advance ordering of specialized paper materials from ACT. The advance planning process allows any needed resources to be assigned appropriately and documented for the examinee.

Typically, examinees who receive this high level of support have a formally documented need and have therefore been identified as qualifying for resources or specialized supports that require expertise, special training, and/or extensive monitoring to select, to administer, and even to use the support effectively and securely. These can include but are not limited to the following examples:

- Braille EBAE, contracted, includes tactile graphics (paper)
- Braille UEB with Nemeth contracted, includes tactile graphics (paper)
- Cued Speech (online and paper)
- Word-to-Word Bilingual Dictionary, ACT approved (online and paper)
- English Audio DVD (designed for user with blindness) (paper)
- English Audio Reader Script (designed for user with blindness) (paper)
- Signed Exact English (SEE): Test Items
- Abacus
- Extra Time

Decisions about accommodation-level supports are typically made by an educational team on behalf of, and including the examinee. Accommodation decisions are normally based on formal, documented evaluation of specialized need and require the examinee to have personal familiarization and successful prior experience with the tools so they may be used fluidly and effectively during the test experience. Accommodation supports require substantial additional local resources or highly specialized, expert knowledge to deliver successfully and securely.

Accommodations are available to users who have been qualified by the local governing school or employment authority to use them, (e.g., a school district, a work training agency, an employer, or a branch of military or other government service). Official determination of qualification for accommodation-level support by a governing school or workforce authority is usually documented in writing in the form of an accommodation plan, or such qualification may have been routinely recognized and permitted for this examinee by that governing authority. NCRC assessments, including the Applied Math assessment, require that examinees who use accommodation-level supports have a formally documented need, as well as relevant knowledge and familiarity with these tools. Accommodations must be requested through the local test site according to WorkKeys assessment procedures, as defined in the administration manual. Appropriate documentation of accommodation need, as specified in the manual, must be provided prior to testing by the examinee, or by a local governing educational authority on behalf of the examinee.

Support Level 4: Modifications

Modifications are supports that are sometimes used during instruction, but when used in a testing situation, they alter the construct that the test is designed to measure. While they may provide an individual with the experience of taking 'a test,' modifications provide so much support that they actually prevent the examinee from having meaningful access to performance of the construct being tested. (See the top level of the pyramid in Figure 5.1.) Because modifications violate the construct being tested, they invalidate performance results and communicate low expectations of examinee achievement. Modifications are not permitted during Applied Math testing and, if used, invalidate the resulting test score.

5.3 Allowable Embedded Tools, Open Access, and Accommodations

In our commitment to provide a fair testing experience for all examinees, ACT WorkKeys NCRC assessments provide an integrated system of accessibility supports that include accommodations as well as other forms (less intensive levels) of accessibility support. There are times when supports provided for those who test using the online format are combined with other types of locally provided or paper-format supports. The reverse is also true, as examinees using the paper format sometimes also take advantage of certain online options. Regardless of test format, all examinees who use accommodation-level accessibility features must have this use documented by appropriate school (or test site) personnel.

5.4 Valid Test Scores and Equal Benefit for All Examinees

ACT aims to ensure that all examinees may benefit equally from the Applied Math assessment. Accommodations and other accessibility supports administered under these standardized conditions result in a valid and fully reportable NCRC score. Use of any accessibility supports that are <u>not specified by ACT</u> or <u>not properly administered</u> violate what the test is designed to measure and result in a score that is invalid and non-comparable for the stated purposes of the assessment.

Section 6: Test and Information Security

6.1 Test Security

In order to ensure the validity of the ACT WorkKeys Applied Math test scores, test takers, individuals that have a role in administering the tests, and those who are otherwise involved in facilitating the testing process must strictly observe ACT's standardized testing policies, including the Test Security Principles and test security requirements. Those requirements are set forth in the *ACT WorkKeys Administration Manual—Paper Testing* and the *ACT WorkKeys Administration Manual—Online Testing* and may be supplemented by ACT from time to time with additional communications to test takers and testing staff.

ACT's test security requirements are designed to ensure that examinees have an equal opportunity to demonstrate their academic achievement and skills, that examinees who do their own work are not unfairly disadvantaged by examinees who do not, and that scores reported for each examinee are valid. Strict observation of the test security requirements is required to safeguard the validity of the results.

Testing staff must protect the confidentiality of the WorkKeys test items and responses. Testing staff should be competent and aware of their roles, including understanding ACT's test administration policies and procedures and acknowledging and avoiding conflicts of interest in their roles as test administrators for WorkKeys.

6.2 Information Security

ACT's Information Security program framework is based on the widely recognized ISO/IEC 27000 standard (International Organization for Standardization, 2017). This framework was selected because it covers a range of information security categories that comprehensively matches the broad perspective that ACT takes in safeguarding information assets.

ACT has developed well defined procedures and processes for the daily handling and safeguarding of secure information, as well as procedures for safeguarding secure information in the event of a disaster or adverse event. The procedures and processes are overseen by the Information Security Officer and all ACT personnel are required to participate in security training. Access to secure information by ACT personnel is limited on a "need to know basis."

ACT's Information Security Incident Response Plan (ISIRP) brings needed resources together in an organized manner to deal with an incident (classified as an adverse event) related to the safety and security of ACT networks, computer systems, and data resources.

The adverse event could come in a variety of forms: technical attacks (e.g., denial of service attack, malicious code attack, exploitation of a vulnerability), unauthorized behavior (e.g., unauthorized access to ACT systems, inappropriate usage of data, loss of physical assets containing Confidential or Confidential Restricted data), or a combination of activities. The purpose of the plan is to outline specific steps to take in the event of any information security incident.

The Information Security Incident Response Plan charters an ACT Security Incident Response Team (ISIRT) with providing an around-the-clock (i.e., 24/7) coordinated security incident response throughout ACT. Information Security management has the responsibility and authority to manage the Information Security Incident Response Team and implement necessary ISIRP actions and decisions during an incident.

Section 7: Preliminary Field Test Data Analyses and Findings

ACT conducted a series of field test studies to better understand the psychometric properties of the Applied Math assessment and to make decisions related to test administration. Specifically, the studies were designed to access the following questions:

- What is the appropriate test time for the Applied Math assessment?
- What is the reliability (internal consistency) of the Applied Math assessment?
- What is the factor structure of the Applied Math assessment?
- Do examinee responses to the assessment items indicate that the IRT assumptions are met?
- How was the primary scale score established and what methods will be used for equating to ensure that scale scores have the same meaning regardless of form?

For each of the field test studies, ACT attempted to recruit samples representative of the regular WorkKeys testing population. Although variability existed in terms of demographic groups amongst the field test studies, each sample consisted of approximately 60% high school students and 40% adult test takers, 55% female and 45% male test takers, and 60% Caucasian, 16% African American, and 8% Hispanic test takers.

7.1 Testing Time Limit

ACT designed the Applied Math assessment to be a power test where examinees are provided adequate time to complete the assessment (Miller, Linn, & Gronlund, 2013). As such, testing time should allow sufficient time for at least 90% of examinees to complete the assessment. In the first field test study, with examinees taking assessments both on paper and online, ACT allowed examinees either 55 or 60 minutes to complete the assessment. With these time conditions, ACT surveyed examinees to learn if they believed that they had sufficient time to complete the assessment.

In the first study, ACT found that the mean testing time was approximately 32 minutes. ACT also learned that 95% of examinees completed the assessment in less than 50 minutes for both the paper and online formats. On the post-administrative surveys, 93% of the examinees who were allowed 55 minutes Agreed or Strongly Agreed with the statement, I had a sufficient amount of time to answer each test question. Of the examinees who were had 60 minutes to test, 98% Agreed or Strongly Agreed with the statement. Based on these findings, ACT concluded that a 55-minute time limit would provide sufficient time.

For the second field test study, ACT continued to evaluate the amount of time that examinees required for testing. In the second field test study, all examinees took the assessment online. The findings of the second field test study confirmed that 55 minutes was a reasonable time limit. In the second study, mean testing time remained approximately the same as in the first study, and 95% of examinees completed all items on the assessments in under 54 minutes. On the post-administrative surveys, approximately 82% of the examinees Agreed or Strongly Agreed with the statement, I had a sufficient amount of time to answer each test question.

Based on the examinee response patterns, completion rates, and survey responses, ACT concluded that allowing examinees 55 minutes to complete the assessment was reasonable and that it would result in the test not being speeded.

7.2 Score Reliability

ACT used Coefficient Alpha to estimate the overall reliability of the Applied Math assessment. Coefficient Alpha is a measure of the internal consistency of the items constituting the assessment. Prior to administration, ACT determined that 0.80 would be a minimal acceptable level of internal consistency. Following the calculation of Coefficient Alpha, ACT calculated the Standard Error of Measurement (SEM). SEM summarizes the amount of error or inconsistency in scores on a test. Scale score SEMs were estimated using a four-parameter beta compound binomial model (Kolen, Hanson, & Brennan, 1992). If the distribution of measurement error is approximated by a normal distribution, true score scores for about two-thirds of the examinees are within plus or minus one SEM from their reported scale score. Table 7.1 presents the reliability estimates and SEM based on data from the second field test study.

Table 7.1: Applied Math—Reliability Estimates and Standard Error of Measurement of Form A and Form B

		Raw Score		Scale Score	
Form	N	Coefficient Alpha	SEM	Coefficient Alpha	SEM
Form A	1,185	0.88	2.16	0.89	1.57
Form B	1,196	0.88	2.11	0.89	1.61

ACT also estimated the reliability of the forms applying a multivariate generalizability framework (Brennan, 2001). Generalizability theory provides estimates of universe score variance, absolute score variance, and absolute error variance. The analysis allows for the calculation of a G-coefficient, which provides an alternative estimate of internal consistency. The G-coefficients estimated for both forms of the Applied Math assessment was 0.89 for both forms. Based on the reliability estimates and SEM, ACT concluded that the Applied Math met the requirements for score reliability.

7.3 Factor Structure

For both the second and third field test studies, ACT used Exploratory factor analysis (EFA) assess dimensionality for the Applied Math assessment. EFA uses an inter-item correlation matrix to identify the underlying factors accounting for the observed variance in the items. In these analyses, four criteria are evaluated to determine dimensionality. A scree plot of eigenvalues can be used to determine the test dimensionality, with unidimensionality indicated by having only one eigenvalue above the “elbow” in the scree plot curve. Hatcher (1994) suggested that a factor should be retained if it accounted for at least 10% of the total variance. Reckase (1979) suggested that if the first factor explains 20% of the variance of a set of items, the item set should be considered unidimensional. Hattie (1985) suggested that the first factor is relatively strong if the factor difference ratio index (FDRI) (Johnson, Yamashiro, & Yu, 2003) is larger than 3. FDRI is defined as the ratio of the difference between the eigenvalue of the first factor and the second factor to the difference between the eigenvalue of second and the third factor.

Table 7.2 summarizes the eigenvalues and FDRI for the Applied Math forms. Evaluation of the scree plots for all three forms indicated a single factor as the “elbow” appeared immediately following the first eigenvalue. Applying the rules of Hatcher (1994), Reckase (1979), and Hattie (1985) also supported the conclusion that each Applied Math form was unidimensional. The data presented in Table 7.2 indicate that more than 10% of the variance on all three forms could be attributed to the first factor and no other factor met the 10% threshold; that the variance attributed to the first factor exceeded 20% on all forms; and the FDRI was larger than 3 for all forms with Form B—online being the smallest (FDRI = 6.10). Collectively, the findings provide strong evidence that the Applied Math assessment is a unidimensional measure.

Table 7.2: Applied Math—Summary of Eigenvalues and Factor Difference Ratio Index (FDRI)

	First Factor	Second Factor	Third Factor
Form A—Online			
Eigenvalue	12.21 (39.4%)	2.70 (8.75%)	1.30 (4.2%)
Difference		9.51	1.41
FDRI			6.75
Form B—Online			
Eigenvalue	12.30 (39.7%)	2.87 (9.2%)	1.32 (4.3%)
Difference		9.43	1.55
FDRI			6.10
Form C—paper			
Eigenvalue	14.47 (46.7%)	2.77 (8.9%)	1.26 (4.1%)
Difference		11.70	1.51
FDRI			7.75
Form C—online			
Eigenvalue	14.75 (47.6%)	2.71 (8.7%)	1.21 (3.9%)
Difference		12.04	1.50
FDRI			8.03

Note. The percentage in the parenthesis is the percentage of total variance accounted for by that factor.

7.4 3-PL IRT Model

The 3-PL IRT model has two major assumptions: (a) item responses are measuring a unidimensional factor and (b) items are locally independence. In the preceding section, ACT analyzed the item responses and concluded that the Applied Math forms were measuring a unidimensional factor. The assumption of local item independence is that examinees’ responses for one item on a form do not affect or influence their responses to any other item on the form. In the case of Applied Math, test items are discrete. Additionally, in form assembly, ACT content staff carefully evaluate each item to ensure that it does not clue or have leading information that might affect how examinees respond to a different item on the form. As a result, the assumption of local item independence is met through the assessment design requiring all discrete test items, and by form construction quality assurance.

With both IRT assumptions met, ACT analyzed item data using a 3-PL IRT model for Forms A and B for the second field test study. Table 7.3 presents the summary IRT parameter estimates for the two forms.

Table 7.3: Summary of IRT Item Parameter Estimates

	IRT a				IRT b				IRT c			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Form A	1.19	0.32	0.73	2.04	0.56	1.28	-1.84	3.09	0.16	0.06	0.05	0.30
Form B	1.23	0.31	0.71	2.04	0.53	1.34	-1.80	2.54	0.17	0.06	0.06	0.31

Figure 7.1 shows the Test Characteristic Curve (TCC) and the Test Information Function (TIF) for the base form administered in the second field test study. The Applied Math TCC and TIF indicate an assessment that provides a good deal of measurement information for examinees who are within two standard deviations of the mean.

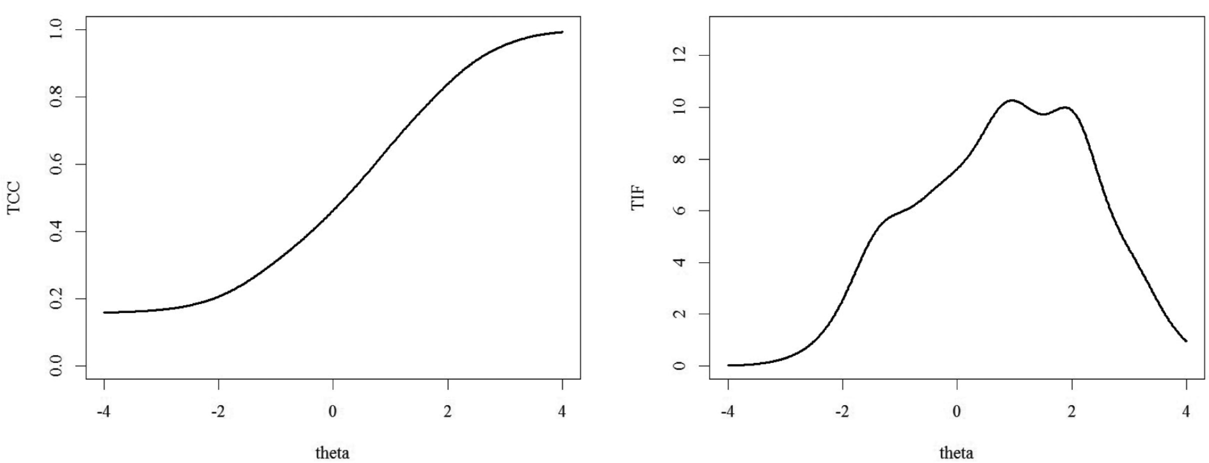

Figure 7.1: Applied Math—Test Characteristic Curve and Test Information Function of Base Form

7.5 Applied Math—Score Scale and Form Equating

The base form score scale was established on the Applied Math assessment using examinee response data from the second field test study. The primary purpose was to develop a score scale so that examinee responses to items on all Applied Math forms could be converted from raw scores to scale scores, and then analyzed and compared on a common score metric. For the scaling, Form A was defined as the Applied Math base form. The scaling process used IRT scaling (Ban & Lee, 2007) and applied the arcsine transformations (Kolen, 1988; Kolen & Brennan, 2004), resulting in the base form raw-to-scale score conversions. By applying the arcsine transformations, the Conditional Standard Errors of Measurement (CSEMs) were relatively equal across the score scale.

ACT set the scale scores to range from 65 to 90, which was the traditional score scale range used for the NCRC assessments. Applying the scale score average and CSEMs of the current WorkKeys 1.0 assessments, the target mean and target CSEM of the arcsine transformation were set to 77.9 and 1.6. Figure 7.2 presents the CSEMs across the full range of scale scores for the base form.

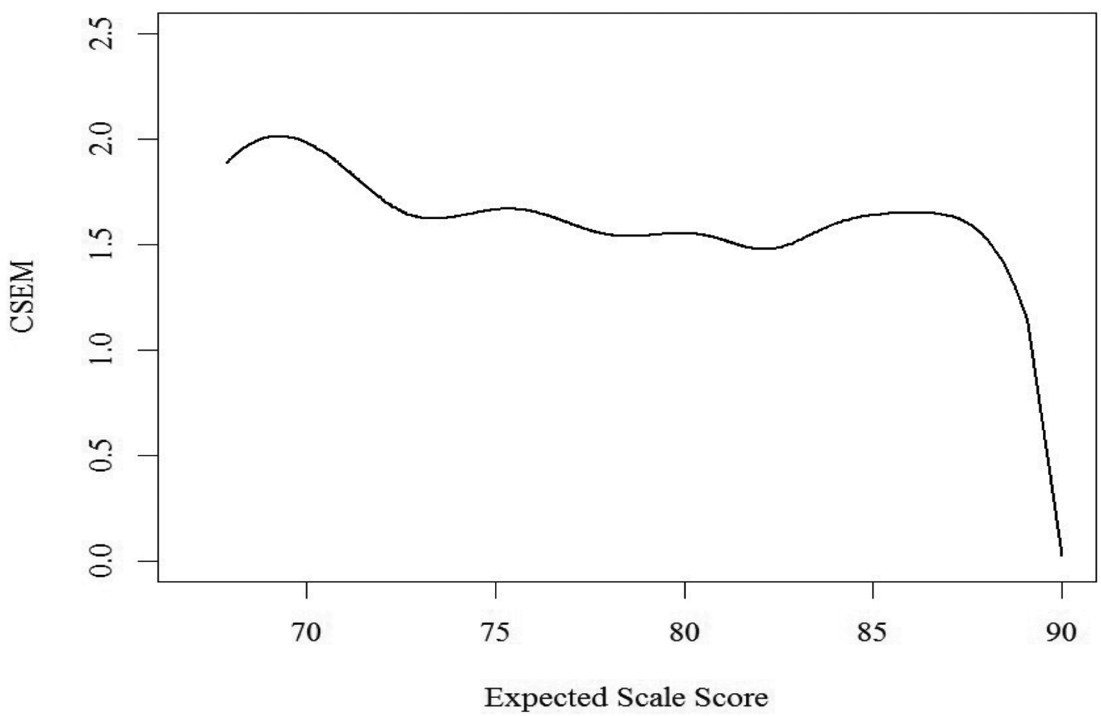

Figure 7.2: Applied Math—Conditional Standard Errors of Measurement for Scale Scores

ACT equated scores from Form B to the base form (Form A) using IRT true score equating (Kolen & Brennan, 2004). Table 7.4 provides the summary scale score statistics for Forms A and B. Based on equated scale scores, examinees who took Form B slightly outperformed examinees who took Form A. Examinees scores indicated approximately equal variability for the two groups.

Table 7.4: Applied Math—Equated Scale Score Summary Statistics

	N	Mean	Median	SD	Min Score	Max Score
Form A	1,185	78.02	78	4.78	65	90
Form B	1,196	78.14	78	4.81	65	90

Section 8: Establishing Level Score Standards

All WorkKeys assessments report to examinees their performance in terms of a scale score and a level score. The interpretation and use of the scale score is appropriate when the assessment is used to evaluate achievement or effectiveness of an educational or training program. The scale scores provide the user with finer performance distinctions than the level score. As such, they are more sensitive to gains achieved through educational or training programs.

WorkKeys level scores should be interpreted and used for selection, promotion, or other high-stakes purposes. WorkKeys assessments were originally developed to be used in conjunction with a job profiling process for employee selection and promotion. The job profiles are aligned to the assessment score levels and not to the more granular scale score.

Section 7 provided information regarding the method ACT applied to develop the Applied Math score scale. Following the development of the Applied Math score scale, ACT conducted a standard setting in order to identify the points on the scale score where examinees who have scored at or above that point have demonstrated the ability to earn a specified level score.

8.1 Standard Setting Method

ACT conducted a standard setting study to establish the minimum scores required to achieve each of the five Applied Math levels. To establish the minimum score, ACT assembled a panel of experts consisting of educators and business people, some of whom are current WorkKeys customers. Because the Applied Math assessment is a criterion-referenced test, scores on the assessment are aligned to a set of skills that an examinee demonstrated. (Please refer to Section 2.4 for detailed PLDs associated with each level score.) The goal of the standard setting process was to identify a point on the score scale where test takers who score at or above the point have demonstrated the ability to perform the skills, and test takers who score below the point have not demonstrated the ability to perform the skills.

The Mapmark with Whole Booklet Feedback standard setting method was used in the study (Schulz & Mitzel, 2005). It is a variation of the popular Bookmark procedure (Lewis, Mitzel, Mercado, and Schulz, 2012). The primary difference between Mapmark and Bookmark is the Item Map. The Ordered Item Booklet (OIB), used in both procedures, has a sample of items from the item pool ordered from easiest to hardest. The Mapmark procedure also includes an Item Map, on which the difficulty of an item is indicated by actual scale value. The Item Map, therefore, shows “how much” more difficult one item is than another item.

Mapmark with Whole Booklet Feedback is a three-round process. In Round 1, the panelists (a) took the Applied Math assessment, (b) reviewed the PLDs, (c) reviewed test items and their associated Scale Score, (d) linked test items to the PLDs, and (e) placed bookmarks in the OIB for each level. Specifically, the panelists were asked to divide the items for each Skill Level into two groups—those items that they felt were easy enough for a minimally qualified examinee in the skill level to have mastered, and those items that were too difficult for a minimally qualified examinee to have mastered. In this context, mastery was defined as having a 2-in-3 chance of success (or a response probability of .67) on the item. This was done to establish the initial cut scores for the five levels (e.g., Levels 3–7).

For Round 2, the panelists received feedback regarding their bookmark placements relative to recommended Scale Scores on the item map scale and to the group's median cut score. The group was then provided with Whole Booklet Feedback. Specifically, they were provided with data showing how fifteen examinees answered each of the items on the base form. Item data was provided for three examinees who scored at or near the Round 1 cut score for each skill level. The purpose was to help the panelists understand what examinees at the Round 1 cut scores "can" do and consider whether this is what examinees "should" be able to do according to each PLD. Using all of this information, panelists were asked to repeat the process of placing bookmarks in the OIB for each level.

For Round 3, panelists received feedback regarding their bookmark placement in Round 2. The feedback consisted of impact or consequential data of their Round 2 placements, which provided the percentage of examinees who achieved at or above the cut scores set for each skill level. ACT emphasized to the panelists that the PLDs should take precedence since the assessments are criterion-referenced. With that, they again placed bookmarks in the OIB.

During the final meeting, the panelists reviewed the Item Map with lines representing the Round 3 median cut scores drawn on the map. Next, they reviewed a Cut Score Distribution Chart showing the distribution of panelists' Round 3 cut scores across all skill levels. Finally, the panelists discussed impact data based on the final cut scores. The panelists approved the final median cut scores to define the five performance levels.

The Design Team reviewed the work of the Standard Setting. Design Team members evaluated whether the work of the panelists achieved the desired result of a criterion-referenced assessment with level scores aligned to the PLDs. After reviewing the panelists' work and recommendations, the Design Team approved the recommended cut scores for the five score levels of the Applied Math assessment.

Section 9: Final Note Regarding On-going Studies

ACT plans to continually collect and analyze data from the Applied Math assessment. These analyses will range from studies of score reliability, factor structure of the assessment, fairness evaluations, and the relationship of assessment scores to significant outcome variables (i.e., job performance ratings, training completion rates and scores, program grades). ACT will periodically publish papers providing the findings of these studies. Additionally, ACT will provide information and analyses in the electronic Technical Manual in an ongoing manner as studies are completed. The information, data, and analyses are designed to provide understanding and insight regarding score interpretations and usage.

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