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WorkKeys Mathematics Skill-Level Scores as Predictors for Placement into College-Level Mathematics

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WORKKEYS MATHEMATICS SKILL-LEVEL SCORES AS PREDICTORS FOR PLACEMENT INTO COLLEGE-LEVEL MATHEMATICS

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SIGNATURE PAGE

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CHAPTER I

INTRODUCTION

The need for a revised, up-to-date and accurate placement test in mathematics courses for undergraduate college freshmen has become increasingly more apparent among many colleges and universities in order to support not only education but also the workforce. Some institutions of higher education had been accustomed to using the standardized Mathematical Association of America (MAA) Placement Test. Others had designed their own exams or used a combination of placement exams and other measurements such as American College Testing Program (ACT) or Scholastic Aptitude Test (SAT) mathematics scores and high school GPAs to determine appropriate placement. When the MAA discontinued its placement test program in 2001 the responsibility of placement was placed on the individual institutions to develop their own methods (Norma & Sokolowski, 2004).

Until recently, community and technical colleges in the United States were typically characterized by open admission policies. Open admission allowed these colleges to accept all students who could profit from an educational experience (Beal, 1971). Though there was typically no admission examination required of entering community and technical college students, an academic skills assessment or placement examination was often required of applicants. Entering students would meet with their academic advisors using the results of the placement examination to determine the appropriate academic level of their initial courses. The intent was to match the skill level of the student to the level of difficulty of the courses in which that student would enroll in order to provide a reasonable opportunity for success (ERIC, 2007). The importance of

accurately assessing academic skills and properly advising community and technical college applicants at entry cannot be overstated, when it comes to forecasting a student's success at the college level.

The potential for success in higher education was multidimensional and difficult to predict. The search for an appropriate assessment tool was found to be difficult since there was always more than one way to measure an objective and no single method was good for measuring the abilities and motivations of a wide variety of students who entered a variety of academic programs. Some critical factors such as individual motivation could be measured objectively. Thus, that which can be objectively measured such as acquired knowledge often became the basis for deciding where the academic entry point should be for entering students. Academic success was largely dependent on competencies. Competence could be thought of as the ability one had to apply knowledge in a particular context. If researchers were able to determine how well an individual could use knowledge in a particular context to solve a problem, they potentially could apply that information to help predict a level of success in that context (Prus & Johnson, 1994).

One of the most popular assessment examinations in use at community and technical colleges was the Assessment of Student Skills for Entry and Transfer (ASSET). The computerized version was the Computer-Adaptive Placement Assessment and Support System/English as a Second Language (COMPASS/ESL). They were products of ACT, formerly known as American College Testing, Inc. American College Testing was founded in the late 1950s as an independent, not-for-profit organization located in Iowa City, Iowa, to accommodate the growth in the number of students approaching

college age and who wanted to enroll in college. They provided assessments, research, information and program management services in the areas of education and workforce development. In 1996, the organization changed its name from American College Testing to ACT, pronounced using the initials A-C-T. Along with other assessment tools, ACT provided the ACT examinations, a competitor of the Scholastic Aptitude Examination (SAT), as well as the ASSET, COMPASS/ESL and WorkKeys.

ASSET was a testing and advising program for placing students into academic courses at most postsecondary institutions. It was a paper and pencil four-part examination that evaluated the level of foundational knowledge in reading, writing, numerical skills and algebra.

COMPASS/ESL was an untimed computerized test. It assessed skills in the same three areas as ASSET. In the mathematics and reading comprehension parts of the COMPASS/ESL examination, the questions were asked in ascending level of difficulty. The test was designed to determine specific academic deficiencies. How well an examinee does was immediately translated into an academic course level in each discipline. ASSET and COMPASS were designed to determine the level of knowledge an individual had but not how to apply that knowledge to solve a problem.

WorkKeys was a comprehensive system for measuring and improving "real world" skills believed to be critical for success in the workplace. WorkKeys evaluated workplace skills in nine skills areas, including Reading for Information, Applied Mathematics, Locating Information, Business Writing, Applied Technology, Observation, Teamwork, Listening and Writing. Three of those skill areas (Applied Mathematics, Reading for Information and Writing) corresponded directly to the

academic skill areas that are generally assessed using ASSET or COMPASS. Whereas ASSET and COMPASS evaluated how much acquired knowledge an individual had, WorkKeys was designed to evaluate a person's ability to use knowledge to solve practical problems. The levels of problem solving or practical skills required for each WorkKeys skill area corresponded to a numerical scale, ranging from one to seven, where one was the lowest and seven was the highest. This scale was criterion-based since each skill level represented a specific set of problem solving abilities that was well-defined and measurable.

Over time, industry became interested in more than just determining who had the skills or knowledge to perform a particular job. In an increasingly unpredictable and dynamic business environment, progressive organizations recognized the need to create what Senge called a "learning organization." In a learning organization people "continually expand their capacity to create the results they truly desire where new and expansive patterns of thinking are nurtured, collective aspiration is set free, and people are continually learning how to learn together" (Senge, 1993, p. 7). Hence, many industrial organizations became committed to the development of their employees' ability to think of ideas and solve problems on their own and to participate as team members. They encouraged them to pursue lifelong learning opportunities through formal education or nontraditional training resources.

An example of an area where individuals were assessed based on their ability to perform well in a learning organization was Region 2000, including the Virginia counties of Amherst, Appomattox, Bedford and Campbell and in the cities of Bedford and Lynchburg, VA. Many employees had taken the WorkKeys assessments during initial

pre-employment screening for companies such as AREVA-NP, Inc., Tyco Electronics, Babcock and Wilcox, Ross Laboratories and the City of Lynchburg's Public Works Department. The examinees were assessed in the three or more skill areas (Reading for Information, Applied Mathematics, Locating Information and Observation), wherein the entry skill levels had been set during the WorkKeys job profiling/analyses for a particular position. Thus, if they had already taken skills tests they could substitute those scores for ASSET or COMPASS/ESL placement examinations.

This approach proved very cost-effective. It would prove to be of particular interest to companies such as AREVA-NP and Tyco Electronics, which routinely used the community or technical colleges to administer the WorkKeys system as part of their pre-employment selection process. These companies paid all or part of the necessary educational costs for their employees. However, many of the Region 2000 employees who took advantage of these learning opportunities often found that the first thing they needed to do after applying to the community or technical college was take an academic placement examination such as COMPASS/ESL, even though their applied mathematics, reading and writing skills would also be evaluated with the WorkKeys tool. The costs incurred by either sponsoring organizations or their employees or both, for the additional tests were considerable because of the expenses associated with test administration, instrument cost, scoring and wages being paid to employees while taking the tests, not to mention production lost.

The researcher designed this study in an effort to determine whether there was a correlation between the WorkKeys Applied Mathematics skill level scores and COMPASS/ESL Mathematics scores. A score on the COMPASS/ESL that falls within a

specified range indicated knowledge equivalent to a particular course level. Hence, if a significantly strong correlation existed between WorkKeys Applied Mathematics skill levels and a certain range for COMPASS/ESL cut-off scores that were associated with a recommended mathematics course placement, then inference could be drawn about the use of WorkKeys as a substitute for COMPASSS/ESL for academic placement into college level mathematics courses.

STATEMENT OF PROBLEM

The problem of this study was to determine the relationship between the WorkKeys Applied Mathematics skill level scores and COMPASS/ESL Mathematics placement scores as predictors for placement into college level mathematics.

HYPOTHESIS

To guide this study, the following hypothesis was established:

H_1: WorkKeys Applied Mathematics skill level scores on the WorkKeys test will be a successful predictor of achievement on the COMPASS/ESL mathematics placement test.

BACKGROUND AND SIGNIFICANCE

Ensuring success in college has not only always been a concern for students but also for community and technical colleges they attend. Accurate predictions regarding course placement led to increased student success. The more successful students were in completing the assessments, the more likely they were to finish their degree. Success for students also led to higher grade point averages, which made them more competitive in the marketplace and which would lead to greater opportunities for professional employment opportunities.

For this reason, Central Virginia Community College (CVCC) began operating a WorkKeys Solution Partner Service Center located on campus in Merritt Hall in 1995. The center has provided services to the Region 2000 businesses and individuals. Some of these services included WorkKeys job profiling, administration of assessments, reporting and documentation of test results. The Center also has offered remediation courses that were aimed specifically at closing skill gaps and for raising skill levels of examinees. The AREVA-NP and Tyco Electronics WorkKeys job profiles that were used as part of the admittance criteria into the Nuclear and Electronics Technologies academic programs were performed by CVCC's certified WorkKeys job profilers.

WorkKeys began growing in popularity across the nation for at least two reasons. First, those who had a WorkKeys profile proved more competitive in the marketplace, because they could be more quickly and successfully placed based on the results of their WorkKeys assessment. Second, accurate placement could be made without requiring additional testing, which could lead to a substantial cost savings to students and sponsoring organizations (ACT, 2007).

The literature has demonstrated the need for published research that compares WorkKeys Applied Mathematics scores to COMPASS/ESL mathematics scores. Thus, this study expects to contribute to a body of knowledge about the relationship between WorkKeys and COMPASS/ESL mathematics placement test.

LIMITATIONS

The limitations of this study were identified as follow:

1. This research was limited to a selected group of subjects: Nuclear and Electronics Technicians from two companies within the service area for CVCC.
2. Only employers who utilized WorkKeys profiles and assessment results in the hiring process were included.

ASSUMPTIONS

This study was based on the following assumptions:

1. The ACT's WorkKeys system was a standardized job skills and assessment system that businesses commonly used for employee selection and training.
2. The level of knowledge among the population varied in mathematics, WorkKeys and COMPASS/ESL, and, thus, could not be effectively measured.
3. WorkKeys scores were a major factor in determining which applicants were hired for the technician positions and who subsequently would enroll in a required academic program.

PROCEDURES

The data the researcher used for this study were obtained from the collection of two sets of data, including WorkKeys skill level scores for Applied Mathematics and the COMPASS/ESL mathematics placement scores for each student. The COMPASS/ESL scores were retrieved from People Soft. Whereas, the WorkKeys scores were collected from Express Score which electronically scored the test of applicants that were seeking employment with AREVA-NP and Tyco Electronics. The WorkKeys skill level scores and COMPASS/ESL scores were then compared and analyzed using Pearson's r

statistical analysis in order to determine if there was a significant statistical relationship and the direction for this relationship.

DEFINITION OF TERMS

The following definitions were provided to assist the readers in their meanings.

Mathematics placement tests: Such tests are either locally developed tests, state or regionally developed tests or commercial nationally normed tests. Regardless of the type of placement test used, the institution had determined appropriate cutoff scores for placement purposes. There was an assumption that the content of the courses was appropriate for the skill being tested.

Job profiling: Job profiling is a job analysis system used to assist businesses in identifying skills and skill levels employees must have to successfully perform particular jobs effectively. It also provides individuals with a clear picture of the skill levels needed to qualify for and be successful in the jobs they apply for.

Pre-employment assessment: Such assessments refer to a test administered to assess an employee's knowledge, skills, abilities or characteristics.

OVERVIEW OF CHAPTERS

Chapter I included an introduction to the problem of this study. Community and technical colleges needed an assessment instrument that would accurately place students into their initial mathematics courses and would provide a reasonable opportunity for success in higher education. ASSET and COMPASS/ESL placement tests were used by most postsecondary institutions for this purpose. Employers' needs differed from community colleges and technical school. They not only wanted to know whether employees could gain knowledge, they also wanted to know how well their employees

could apply the knowledge they gained in the workplace. That is why community colleges and technical schools began administering the WorkKeys system for measuring and improving skills believed to be critical to success in the workplace. This system began being used by business and industry for pre-employment screening, who were interested in more than just determining who had the skills to perform a particular job. Whereas ASSET and COMPASS/ESL evaluated how much knowledge an individual had, WorkKeys was designed to evaluate a person's ability to use knowledge to solve practical problems. The problem of this study was initiated to determine if there was any relationship and possible alignment between WorkKeys Applied Mathematics skill level scores and COMPASS/ESL Mathematics placement scores for Region 2000 Nuclear and Electronics technicians.

Chapter II provides a review of literature that will describe the construct validity of COMPASS and WorkKeys and other research that has been conducted on alternate placement tests in college mathematics courses. Chapter III describes the methods and procedures used in this research study. Chapter IV presents the results of the study. Finally, Chapter V will summarize the results of this study and will present recommendations for continuing and future research.

CHAPTER II

REVIEW OF LITERATURE

This chapter will provide a review of literature for this study. To provide support for this study, Chapter II will discuss the purpose of course placement and present an overview of COMPASS/ESL placement tests and the WorkKeys® Applied Mathematics skills assessment and their related validity evidence. Chapter II will then examine other mathematics placement tests as well their validity evidence.

PURPOSE OF COURSE PLACEMENT

Course placement had became established over the last two decades as an area of decision making in many postsecondary institutions, particularly in colleges with open admissions policies. Course placement decisions typically involve assigning a student to either a standard or lower level, sometimes called "developmental" or "pre-curriculum" course.

The American Mathematical Association of Two-Year Colleges (AMATYC) provides a concise and explicit description of the purpose behind academic placement. AMATYC recommends that all two-year colleges develop procedures for the initial placement of two-year college students into the curriculum. The placement process should determine the highest level of mathematics appropriate to the student's educational goals at which they have the prerequisite knowledge to be successful. The criteria used to determine mathematics placement should be based on the goals of the mathematics program. AMTYC also stated that placement tests should provide a measure of student's abilities not only to show mastery skills but also to think critically and solve problems (AMATYC, 2008).

AMATCY recognized that student success could be impacted by less quantifiable factors such as motivation, family and work obligations, special student needs and educational and personal goals. Consequently, AMATYC recommended that final decisions regarding placement should be based on an analysis of multiple measures, not just placement test results.

COMPASS/ESL PLACEMENT TESTS

The Computer-Adaptive Placement Assessment and Support System/English as a Second Language (COMPASS/ESL) was a comprehensive assessment, advising, retention and outcomes-oriented system of services. ACT developed COMPASS/ESL to help postsecondary institutions expand opportunities and increase the likelihood that entering students would achieve educational success and retention. COMPASS/ESL was untimed and computer-adaptive (ACT, 2006).

COMPASS/ESL provided measures of key skills useful for placing students into standard courses in the areas of writing, reading and mathematics, and, if needed, into English as a Second Language courses. The standard COMPASS placement measured Mathematics, Reading and Writing Skills, and e-Write was designed to assist institutions in placing students into appropriate college-credit courses or developmental or preparation courses. The measures resulted in a total of up to eight possible placement scores (one each in Writing Skills, e-Write and Reading and up to five in Mathematics, including Numerical Skills/Pre-algebra, Algebra, College Algebra, Trigonometry and Geometry). Thus, because this study was about placement into college level mathematics courses the researcher only included literature related to the validity evidence for the COMPASS/ESL mathematics placement test (ACT, 2006).

The COMPASS Mathematics Tests were developed around five content domains: numerical skills/pre-algebra, algebra, college algebra, geometry and trigonometry (ACT, 2006). Students could be tested for placement purposes in one or more of those content domains. Each of the five content domains contained a pool of about 200 or more five-option multiple-choice items. ACT staff worked with panels of experts and content consultants to determine specific knowledge and skills to be tested in each domain. To ensure variety in the content and complexity of items within each domain, ACT solicits mathematics items of three general levels of cognitive complexity: basic skills, application and analysis. A basic skills item could be solved by performing a sequence of basic operations. An application item involved applying sequences of basic operations to novel settings or in complex ways. An analysis item required examinees to demonstrate a conceptual understanding of the principles and relationships relevant to particular mathematical operations. Items in each of the content domains were sampled extensively from those three cognitive levels.

The five domains were roughly hierarchical, particularly in the three algebra domains. The geometry domain parallels the middle- to upper-algebra domains. The trigonometry domain required the most sophisticated and complex mathematical competence. Adjoining content domains overlapped in some topic areas to reflect the content overlap that was built into college mathematics courses and to make the shift from one content domain to another minimally disruptive to the examinee (ACT, 2006).

The Numerical Skills/Pre-algebra Placement Test was the most elementary of the five Mathematics Placement Tests. Typically, students were administered this test if they had a limited or an undetermined exposure to algebra, had performed poorly in previous

algebra courses or had not used their algebra training for a long time (ACT, 2006). Scores from this test were used to place students into an elementary algebra course at the college level or to help determine whether students should be placed below that level (e.g., into a pre-algebra, arithmetic or appropriate "refresher" course). Students who did poorly on this test were routed to the end of the Mathematics Placement Tests. However, students who do well on this test may need to be routed to one or more other Mathematics Placement Tests to determine whether they should be placed into an intermediate algebra or higher-level course. Items in the Numerical Skills/Pre-algebra Placement Test ranged in content from basic arithmetic concepts and skills (e.g., basic operations with integers, fractions and decimals) to the knowledge and skills considered prerequisites for a first algebra course (e.g., understanding and use of exponents, absolute values and percentages) (ACT, 2006).

The Algebra Placement Test was most appropriate for students who had recently completed a pre-algebra or a basic algebra course and for students whose current level of performance suggested a lack of readiness for a college-level algebra course (ACT, 2006). In addition, students who scored high on the Numerical Skills/Pre-algebra Placement Test or low on the College Algebra Placement Test should be routed to the Algebra Placement Test to clarify their current level of competence. Scores on the Algebra Placement Test could be used in conjunction with other available information to help guide decisions regarding placement in basic, intermediate or college algebra courses and other mathematics courses that required a similar degree of mathematical competence. It was composed of items from three curricular areas: elementary algebra, coordinate geometry and intermediate algebra. Each of those three areas was further

subdivided into a number of more specific content areas. Students who scored high on the Algebra Placement Test could be routed to the College Algebra or Geometry Placement Tests. Students who scored low on the Algebra Placement Test could be routed to the Numerical Skills/Pre-algebra Placement Test (ACT, 2006).

The College Algebra Placement Test was most appropriate for students who had recently demonstrated proficiency in intermediate algebra courses. Students who scored high in the Algebra Placement Test could also be routed to the College Algebra Placement Test.

Items in the college algebra item pool tested algebra knowledge and skills in a variety of content areas such as functions, operations with matrices and factorials. Students who scored low on the College Algebra Placement Test could be routed to the Algebra Placement Test. Students who scored fairly high on the College Algebra Placement Test could be routed to the Geometry or Trigonometry placement tests if such information was considered relevant to a particular placement decision (ACT, 2006).

The Geometry Placement Test assessed students' understanding of concepts in Euclidean geometry and students' ability to use spatial/geometric reasoning in problem solving. Scores in this test provided useful information to supplement scores in the Algebra, College Algebra and/or Trigonometry placement tests (ACT, 2006).

The Trigonometry Placement Test assessed students' understanding of trigonometric concepts and their application in problem solving. Scores in this test could be used in conjunction with scores in the College Algebra Placement Test and other available information to help guide decisions regarding placement into college algebra,

trigonometry, calculus or other college-level courses that required similar mathematical proficiency (ACT, 2006).

COMPASS/ESL PLACEMENT TEST VALIDITY EVIDENCE

According to the Standards for Educational and Psychological Testing, the concept of validity referred to "the appropriateness, meaningfulness, and usefulness of the specific inferences made from test scores" (American Psychological Association, 1985, p. 96). Each particular use of test scores needed to be justified by an argument for validity. According to ACT there were two principle uses of COMPASS/ESL: (1) measuring entering college students' educational knowledge and skills and (2) assisting students and college officials in making course placement decisions (ACT, 2006).

Measuring Educational Knowledge and Skills

A major aspect of the current validity evidence for the COMPASS/ESL tests related to content validity. The basic concept for developing those tests was that the best way to predict students' success in a given course was to measure, as directly as possible, the skills and knowledge students needed to succeed in that course. A wide range of input on the nature and content of college curricula went into constructing the COMPASS/ESL tests, thus ensuring a strong match between test and course content.

Content validity for computerized adaptive tests differed somewhat from content validity in conventional tests. In adaptive testing, this concept applied to the representativeness of (1) the item pools from which the adaptive test items were drawn and (2) the adaptive tests that were computer-selected for each student. The COMPASS/ESL system of adaptive tests was designed to ensure that content validity was maintained both for the item pools and the individualized tests (ACT, 2006).

Making Course Placement Decisions

As was the case with most placement testing systems, COMPASS/ESL test scores were intended for placing students into college courses. The elements of the validity argument supporting that use included the following:

- The COMPASS/ESL tests measured the skills and knowledge students needed to succeed in specific courses.
- Students who had the skills and knowledge necessary to succeed in specific courses were likely to perform satisfactorily on the COMPASS/ESL tests and students without those skills would not.
- Higher levels of proficiency on the COMPASS/ESL tests were related to higher levels of satisfactory performance in the course (ACT, 2006).

If course placement was a valid use of those tests, then a significant, positive statistical relationship between COMPASS/ESL test scores and course grades would be expected.

In addition to the use of correlation coefficients and related indices, the present study employed logistic regression procedures as an alternative methodology (developed by ACT) to provide more information and useful validity evidence (Sawyer, 1989). As outlined in *ACT's COMPASS/ESL Technical Manual*, the correlation approach had three main limitations:

> (1) Correlation coefficients provided little direct information about the effectiveness of test scores for placing students into courses, and were easily misinterpreted; (2) Correlations indicated the direction and strength of the relationship between test scores and course

> grades, but the procedure made several statistical assumptions (particularly the assumption of normality of course grades, equal variance, and linear relationship between predictor and outcome measures) that may not be warranted; (3) Correlations did not take into account the cost of incorrect placement decisions. In contrast to using simple correlation coefficients, logistic regression enabled one to estimate the probability of success (e.g., a grade of B or better or a grade of C or better) in the standard courses for all tested students and, in particular, allowed the calculation of the percentage of students correctly placed (i.e., the accuracy rate) (ACT, 2006).

Evidence of Predictive Validity for the COMPASS/ESL

Since the fall of 1993, COMPASS/ESL placement test had been administered to entering freshmen at postsecondary institutions. Those institutions had provided end-of-semester grades for their tested students for a special validity study conducted ACT's Course Placement Service. All of the data that was collected had been analyzed to supply criterion-related validity evidence for the COMPASS Mathematics test. The analyses included only courses that had grades and test scores available for at least 40 students (ACT, 2006).

Logistic regression models were used to calculate estimated probabilities of success for standard-level mathematics courses that had a lower-level course in which a student could be placed. The standard level courses were Arithmetic Skills, Technical

Mathematics, Elementary Algebra, Intermediate Algebra, College Algebra, Pre-calculus and Calculus. The course success was predicted from the relevant COMPASS/ESL test score used as the criterion a course grade of B or higher and C or higher. The estimated probabilities were used to calculate the estimated percentage of students who would be assigned to the lower-level mathematics class (for a particular cutoff score and the estimated accuracy rates (the estimated percentage of student correctly placed) (ACT, 2006).

Table 1 and Table 2 summarized the results of COMPASS/ESL user colleges' participation in the Course Placement Services between January 1995 and November, 2001. Table 1 analyses was based on students obtaining a B or higher. Table 2 analyses were based on students obtaining a C or higher.

In Table 1 and Table 2, a cutoff score for a particular college was defined as the minimum score for which a student had a 50% chance of success in the indicated course. Success was defined as completing the course with a B or high grade in Table 1 or a C or higher grade in Table 2. The cutoff score range and the median cutoff score in the tables pertained to the results summarized over colleges. Accuracy rate was the estimated percentage of students correctly placed with a college's cutoff score. The percent ready for course was the percentage of students whose COMPASS/ESL scores were at or above the median cutoff score. The increase in accuracy rate for a given college was the difference between the estimated accuracy rate with a college's cutoff score and the estimated accuracy rate that would occur if no placement assessment had been used.

Table 1**. COMPASS Cutoff Scores and Validity Statistics for Placement in First-Year Mathematics Courses in College (B or Higher Course Grade)**

Course Type	COMPASS Test Score	Number of Colleges	Cutoff Score Statistics		Validity Statistics	
			Mean Cutoff Score	Percent Ready for Course	Median Accuracy Rate	Median Increase in Accuracy Rate
Mathematics Courses						
Arithmetic	Numerical Skills	26	36	54	70	16
Elementary Algebra	Pre-algebra Numerical Skills	38	62	19	67	25
Intermediate Algebra	Pre-algebra Algebra	29	48	19	71	25
College Algebra	Algebra	23	71	6	72	43
Pre-Calculus	Algebra	6	79	4	78	53
Calculus	College Algebra	6	59	23	65	24

Note. From *Information for Life's Transition: An ACT Program for Educational Planning* (p. 99), by ACT, 2006, Iowa City, IA: ACT.

Table 2. **COMPASS Cutoff Scores and Validity Statistics for Placement in First-Year Mathematics Courses in College (C or Higher Course Grade)**

Course Type	COMPASS Test Score	Number of Colleges	Cutoff Score Statistics		Validity Statistics	
			Mean Cutoff Score	Percent Ready for Course	Median Accuracy Rate	Median Increase in Accuracy Rate
Mathematics Courses						
Arithmetic	Numerical Skills Prealgebra	16	31	63	72	4
Elementary Algebra	Numerical Skills Prealgebra	24	40	47	63	6
Intermediate Algebra	Algebra	17	28	50	68	5
College Algebra	Algebra	19	48	19	67	20
Pre-Calculus	Algebra	5	48	19	59	12
Calculus	College Algebra	4	43	54	68	9

Note. From *Information for Life's Transition: An ACT Program for Educational Planning* (p. 100), by ACT, 2006, Iowa City, IA: ACT.

The goal of an effective placement program was to match students with the instruction appropriate to their educational development. Under that definition, placement validity could be established by calculating the percentage of students correctly placed (i.e., accuracy rate) given the cutoff scores used to place students. Accuracy rates and increases in accuracy rates relative to using no cutoff score (i.e., placing all students in the standard-level course) provided strong validity evidence. Thus,

for example, the first row of Table 1 could be interpreted as follows: 26 institutions, each with a Mathematics arithmetic course, each tested at least 40 students using COMPASS/ESL Numerical Skills/Pre-algebra Placement Test. The median optimal cutoff score was 36. This optimal cutoff score was defined as the score that corresponded to a .50 probability that a student would get a grade of B or higher in the standard arithmetic course (ACT, 2006).

When the optimal cutoff score was used, the median percentage of students placed in the standard-level course was 54%. The median accuracy rate, consisting of the percent of students appropriately placed in either the standard-level or the developmental Mathematics course, was 70%. This represented a 16% increase in appropriate placement over using no placement test.

Table 3 summarized COMPASS cutoff scores for placement in different types of first-year courses. A cutoff score was the minimum score for which ACT estimated that a student had a 50% chance of earning a B or higher (or C or higher) grade in a particular type of course. The B or higher cutoff scores were larger than the C or higher cutoff scores because in a given course, it is more difficult to earn a B than to earn a C.

Table 3. **COMPASS Cutoff Score Guide for Placement in First-Year Mathematics Courses**

Course Type (Number of Colleges)	COMPASS Test Score	Score needed for 50% chance of …	
		B or Higher	C or Higher
	Mathematics Courses		
Arithmetic (15)	Numerical Skills Pre-algebra	36	31
Elementary Algebra (23)	Numerical Skills Pre-algebra	62	40
Intermediate Algebra (19)	Algebra	48	28
College Algebra (18)	Algebra	71	48
Pre-Calculus (4)	Algebra	79	48
Calculus (2)	College Algebra	59	43
Technical Math (2)	Algebra	40	Not Available

Note. From *Information for Life's Transition: An ACT Program for Educational Planning* (p. 101), by ACT, 2006, Iowa City, IA: ACT.

A short overview of the standard placement test utilized at CVCC follows.

COMPASS/ESL Mathematics

The computerized adaptive COMPASS/ESL Mathematics Placement Test administered at CVCC included four content domains: Pre-Algebra, Algebra, College Algebra and Trigonometry. Multiple-choice items in each area tested the following: basic skills (performing a sequence of basic operations), application (applying sequences of basic operations to novel settings or in complex ways) and analysis (demonstrating conceptual understanding of principles and relationships for mathematical operations). Students were permitted to use a calculator when completing the mathematics placement

test. Table 4 lists the CVCC COMPASS/ESL Mathematics cutoff scores that were used for mathematics placement of the forty-eight students in the Nuclear and Electronics Technologies program who were administered the COMPASS/ESL mathematics placement test and subsequently enrolled in the recommended course.

Table 4. **CVCC's COMPASS/ESL Mathematics Placement Cutoff Scores**

COMPASS/ESL Scores	Recommended Courses
	Pre-Algebra
0 – 33	MTH 02 – Arithmetic
	Algebra
34 – 43	MTH 03 – Algebra I MTH 04 – Algebra II MTH 103 – Applied Technical Math I MTH 115 – Technical Math I MTH 116 – Technical Math II MTH 120 – Introduction to Math MTH 121 – Fundamentals of Math I MTH 151 – Math for Liberal Arts I MTH 152 – Math for Liberal Arts II
	College Algebra
41 – 99	MTH 163 – Pre-calculus I
44 – 99	MTH 173 – Calculus with Analytic Geometry MTH 240 – Statistics MTH 271 – Applied Calculus I

Note. From *Central Virginia Community College COMPASS/ESL Cut-off Scores,* 2007.

ASSESSING EMPLOYABILITY SKILLS

Technical education dealt with providing people with workplace skills. While many educators felt it was important to assess the academic skills of first time college students to ensure proper placement in academic courses, employers likewise were keen to assess the workplace skills of potential and current employees to ensure a proper match between ability and job requirements. The term "employability skills" was often used to describe the preparation or foundational skills upon which a person must build job-specific skills (i.e., those that were unique to specific jobs). Among these foundational skills were those which related to communication, personal and interpersonal relationships, problem solving and management or organizational processes (Lankard, 1990).

In the past employability skills were considered to be primarily of a vocational or job specific nature; they were not thought to include the academic skills most commonly taught in the schools. However, current thinking had broadened the definition of employability skills to include not only many foundational academic skills, but also a variety of attitudes and habits (Saterfield, 1995).

Increasingly assessments were being developed specifically from the knowledge and skills needed in workplaces. Thousands of high school students in career and technical education had been tested using WorkKeys (Saterfield, 1995).

The WorkKeys® assessment system was developed by ACT to help students, employers, job applicants and incumbent workers improve employee job fit and to efficiently identify skills gaps. ACT worked closely with educators and employers in developing what they hoped would become the first national system to enable

individuals, educators and employers to improve the skills and quality of the U.S. workforce. Initially developed in 1991, ACT's goal was to measure an individual skill rather than knowledge. ACT first released assessments in Applied Mathematics, Reading for Information, Listening and Writing in 1992. In 1993, Applied Technology, Locating Information and Teamwork were added. Later, Business Writing, Observation and Readiness assessments were developed (McLarty & Palmer, 1994).

Beyond offering only a generic assessment of skill areas, WorkKeys was a criterion-referenced test that was directly related to the requirements of a specific job. Through the use of job profiling, WorkKeys offered a concrete way for organizations to analyze the skills needed for specific jobs and described those needs to job applicants. Trained WorkKeys profilers conducted the job analyses. Subject matter experts (SME) were individuals who were familiar with the job being profiled. They typically included job incumbents and could include their supervisors or other employees who were familiar with the job. Together those individuals determined what entry-level skills were required for a position. Through an extensive multi-day analysis process, six or eight SMEs and the profiler compiled information about the skills required for a job as well as the skill levels necessary for success in the position. Utilizing this system, the WorkKeys profiling procedures conform to the Uniform Guidelines of Employee Selection Procedures (1978).

WorkKeys tests were performance based, simulating real-life situations that examinees might face in employment settings. The Applied Mathematics, Applied Technology, Locating Information, Observation, Reading for Information and Teamwork tests were multiple-choice assessments and were administered either by paper-and-pencil

or computer-based formats. The Business Writing test provided one prompt, allowing test takers to then provide a written response in paragraph form. The Listening and Writing test were given via audiotape. Those tests were scored twice in order to determine the test taker's writing skill level and their listening, recording and retention of information abilities. The Observation and Teamwork assessments were administered via videotapes along with multiple-choice questions.

The lowest score available for a particular test was defined as the lowest level an employer would want assessed. The highest-level score was defined as the maximum level an employer would expect an employee to score without specialized training (McLarty & Vansickle, 1997). In order to have mastery of a skill level, an examinee must have correctly answered at least 80 percent of the items in the test for a particular level. Those levels were statistically verified to be hierarchical. Assessment scores linked directly to the skill levels used in job profiling, which gave employers and educators a common language to discuss skill level needs.

The WorkKeys Applied Mathematics assessment measured the skill people use when they apply mathematical reasoning, critical thinking and problem-solving techniques to work-related problems. The test questions required the examinee to set up and solve the types of problems and do the types of calculations that actually occurred in the workplace. The test was taken with the aid of a calculator. A formula sheet that included all formulas required for the assessment was provided. A description of the skills and the format can be found in Table 5.

Table 5. **WorkKeys Assessments and Formats**

Assessment	No. Items/ Messages	Internet Version Time	Paper-Pencil Time	Audio or Video Component	Low Score	High Score
Applied Mathematics	33	55 min.	45 min.	N	3	7
Reading for Information	33	55 min.	45 min.	N	3	7
Locating Information	38	55 min.	45 min.	N	3	6
Business Writing	1 prompt	30 min.	30 min	N	N/A	N/A
Writing	6 messages	N/A	40 min.	Y	N/A	N/A
Teamwork	36	N/A	64 min.	Y	N/A	N/A
Observation	36	N/A	60 min.	Y	N/A	N/A
Listening	6 messages	N/A	40 min.	Y	N/A	N/A
Applied Technology	32	55 min.	45 min.	N	3	6
Readiness	20 Read 15 Math	N/A	40 min.	N	3	7

Note. From *WorkKeys Assessment Technical Bulletin* (p. 5), by ACT, 2007, Iowa City, IA: ACT.

The skill level definitions "are designed to be arbitrary but standardized, particular to each skill" (McLarty & Vansickle, 1997, p. 298). For example, a skill level of "4" in Applied Mathematics did not mean the same as a skill level of "4" in Listening. Additionally, skill levels in no way were tied to grade levels. However, there was a link between the job analysis and the individual's assessment scores but not between skill areas (McLarty & Vansickle, 1997). An examinee with a skill level of "5" in an assessment area should have mastery of all levels up to and including 5, but not have mastery of higher skill levels. WorkKeys skill levels required for a job corresponded to the most complex skill-related task associated with that particular position.

WORKKEYS VALIDITY EVIDENCE

The Uniformed Guidelines on Employee Selection Procedures (1978) noted that validity may be established through construct, content or criterion-relatedness. Construct validation linked a trait or construct believed important for job performance to actual job behavior. Criterion-related validation statistically related test scores to job performance ratings and content validation demonstrated that the test measures a representative sample of important aspects of the job. The ACT WorkKeys Assessment Technical Bulletin (2006) stated that WorkKeys used content validation based on the job analysis conducted for each position. That profiling analysis defined the critical job task and related them to relevant WorkKeys skills and the level of skill required for a position.

Thus, for tests to function as intended, the scores needed to be reliable and valid. ACT defined reliability as "the correlation between two parallel forms of a test" (Gulliksen, 1987, p. 13), usually reported in terms of a reliability coefficient between 0 and 1. Because WorkKeys test were classification test, reliability coefficients had limited meaning for the assessment. Thus, the Standards of Educational and Psychological Test recommended that publishers of such test provide information about the percentage of examinees that would be classified in the same way on two applications of the same form or alternate forms (American Educational Research Association et. al., 1999). ACT had provided data on the proportion or percentage of examinees who would be classified the same way by two parallel tests that showed exact score consistencies and at-or above classification consistencies for multiple-choice assessments. This data is shown in Table 6.

Table 6. **Predicted Classification Consistency**

Type of Classification	Teamwork	Applied Math	Applied Technology	Locating Information	Observation	Reading for Information
Exact	52	75	59	50	50	46
≥ 3	94	83	89	91	96	88
≥ 4	84	93	78	82	90	71
≥ 5	81	97	88	84	78	79
≥ 6	91	100	100	93	84	97
≥ 7	97	--	--	--	96	--

Note. From *WorkKeys Assessment Technical Bulletin* (pp. 12-15), by ACT, 2007, Iowa City, IA: ACT.

More recently, ACT had evaluated some WorkKeys test scores in three categories that reflect test reliability: internal consistency, generalizability and classification consistency. ACT reported an internal consistency +0.92 reliability coefficient for two forms of Applied Mathematics as tested in 2002 and 2003. This value was considered high for the 30 item tests administration and reflected good internal consistency (ACT, 2007).

Cronbach's generalizability theory provided a framework for evaluating measurement precision, including error variance and error magnitudes related to sampling variabilities (Cronbach, et. al., 1972). ACT's 2007 generalizability analyses for the Applied Mathematics assessment were conducted using data based on 1326 test takers. The mean, standard deviation, skewness and kurtosis of number-correct scores for these examinees were 19.094, 5.765, -0.219 and 2.553, respectively. These scores were representative of results of ACT studies on other assessment tests in the WorkKeys battery. Reliability coefficient were determined to be above +.88 for the Applied Mathematics test, which reflected a high generalizability (ACT, 2007).

The standard error of measurement (SEM) was also closely related to test reliability. The SEM indicated the amount of error of inconsistency in scores on a test. ACT reported scale score reliability estimates based on 2002 and 2003 testing samples using a 3PL IRT model of 0.91 and 0.89 for Applied Mathematics. These results suggested that the tests were reliable and scores would remain fairly consistent if examinees were to retest using alternate forms of the tests (ACT, 2007).

Based on 2002 and 2003 results of a mid-western state's data studied by ACT, classification consistency for all tests was very high. Classification consistency was defined as the proportion or percentage of test takers who would be classified the same way by two parallel tests. At or above classification consistency of Applied Mathematics score were estimated to be between 88 percent and 97 percent (ACT, 2007).

ACCUPLACER COLLEGE PLACEMENT EXAMINATION

The ACCUPLACER was a comprehensive battery of computerized placement tests for incoming college students that had several important features for helping colleges and universities make important course placement decisions (College Board, 2003). Tests within the ACCUPLACER battery were delivered over the Internet to provide fast and accurate determination of whether a student had the skill to take a freshman course or would benefit most from developmental work. According to the College Board (2003), the ACCUPLACER was introduced in 1985 and was meant to place student in English and mathematics courses. At that time it consisted of four tests: Reading Comprehension, Sentence Skills, Arithmetic and Elementary Algebra. But, later the ACCUPLACER battery consisted of nine different sub tests, including General Assessments, Reading Comprehension, Sentence Skills, Arithmetic, Elementary Algebra,

College Level Mathematics, WritPlacer®Plus, Assessment of English Proficiency and WritPlacer ESL. Thus, this literature review will only cover the Mathematics battery including Arithmetic, Elementary Algebra and College Level Mathematics.

The purpose of the ACCUPLACER test was to determine which course placements were appropriate and to determine if remedial work was needed. The ACCUPLACER was not meant to serve as an admission test. Each test in the ACCUPLACER was designed to evaluate a student's ability in a specific academic area. The ACCUPLACER was composed of four sections: Computerized Placement Tests (CPTs), Computerized Placement Advising and Management Software (CPAM), Placement Validation and Retention Service (PVRS) and School to College Placement Articulation Software Service (SCPASS) (Impara & Plake, 1989).

According to the College Board (2003), the ACCUPLACER tailored the test to each student using an item-selection algorithm. The purpose of the algorithm was to match item difficulty to examinee proficiency (College Board, 2003). The student's response to a question then determined the level of difficulty for the subsequent questions.

The Math portion of the ACCUPLACER included 16 questions from three broad categories: 1) operations of whole numbers and fractions including addition , subtraction, multiplication, division, recognizing equivalent fractions and mixed numbers; 2) operations with decimals and percents including addition, subtraction, multiplication, division, percent problems, decimals recognition, fractions, percent equivalencies and estimation problems; and 3) application and problem solving including rate, percent, measurement problems and geometry. While students typically rely on the use of

calculators to complete math exam problems in high school or on the ACT, calculators were not to be used while taking the ACCUPLACER (College Board, 2003).

ACCUPLACER VALIDITY EVIDENCE

According to the Standards for Educational and Psychological Testing (AERA, APA, NCME, 1999), validity refers to the degree to which evidence and theory supports the interpretations of test scores entailed by proposed uses of tests. Validity was the extent to which the inferences (interpretations) derived from test scores were justifiable from both scientific and equity perspectives. For decisions based on test scores to be valid, the use of a test for a particular purpose must be supported by theory and empirical evidence, and biases in the measurement process must be ruled out.

To make the task of validating inferences derived from test scores both scientifically sound and manageable, Kane (1992) proposed an "argument-based approach to validity." In this approach, the validator builds an argument based on empirical evidence to support the use of a test for a particular purpose. Although this validation framework acknowledged that validity can never be established absolutely, it required evidence that (a) the test measured what it claims to measure, (b) the test scores displayed adequate reliability and (c) test scores displayed relationships with other variables in a manner congruent with its predicted properties. Kane's practical perspective was congruent with the Standards for Educational and Psychological Testing (AERA et al., 1999), which provided detailed guidance regarding the types of evidence that should be brought forward to support the use of a test for a particular purpose. For example, the Standards stated:

> A sound validity argument integrates various strands of evidence into a coherent account of the degree to which existing evidence and theory support the intended interpretation of test scores for specific uses…Ultimately, the validity of an intended interpretation…relies on all the available evidence relevant to the technical quality of a testing system. This includes evidence of careful test construction; adequate score reliability; appropriate test administration and scoring; accurate score scaling, equating, and standard setting; and careful attention to fairness for all examinees… (p. 17).

To build a validity argument for a test, there are several types of evidence that could be brought forward. Traditionally, the major forms of validity evidence were content validity, criterion-related validity and construct validity. Content validity evidence involved gathering data from content experts regarding the degree to which the behaviors sampled on the test represented the behaviors the test was designed to measure. Criterion-related validity evidence involved evaluating correlations among test scores and other variables related to the construct measured. Predictive and concurrent validity were special cases of criterion-related validity that involved correlating test scores with future or current criterion performance. With respect to ACCUPLACER, many criterion-related validity studies looked at the correlation between ACCUPLACER scores and final course grades. Construct validity involved gathering data that showed test scores were indicative of the construct measured. Many test theorists (e.g., AERA et al. 1999; Messick, 1989) considered content and criterion validity to be subcomponents of construct validity because such evidence assisted in evaluating test-construct congruence.

For ACCUPLACER scores, evidence of content and predictive validity was particularly important. For a test to be used to identify subject area deficiencies that required placement in developmental courses, the test needed to contain content relevant to that subject area. In addition, the placement test scores should be predictive of students' performance in the course where his or her success was predicted.

Sireci (1998a, 1998b) described four critical aspects of content validity: (a) domain definition, (b) domain representation, (c) domain relevance and (d) appropriate test construction procedures. For the content of a test to be considered valid, the subject domain tested should be clearly defined and external content specialists should verify that the items represent the intended domain and they were relevant to that domain. The College Board had conducted numerous quality control checks on ACCUPLACER test items to determine that they were relevant to the domain assessed, thereby demonstrating content validity. In addition, all items were coded according to their content specifications within the computerized item selection algorithm, which ensured that all examinees got the appropriate breadth and depth of test content as delineated in the test specifications. Furthermore, ACCUPLACER items underwent comprehensive sensitivity reviews to ensure no offensive or derogatory material was present. Thus, the degree to which ACCPLACER tests represented their intended domains was high

According to the ACUPLACER technical manual numerous studies of the degree to which ACCUPLACER test scores were related to students' subsequent course grades had been conducted. Some of these studies had cut across institutions and were coordinated by the College Board. Many other studies were conducted by specific institutions to help evaluate the utility of ACCUPLACER for making placement

decisions or to help determine the most appropriate ACCUPLACER cut scores for their school (College Board, 2003).

A large-scale study of the predictive validity of the ACCUPLACER tests began in January 1990 and continued through early 1992. The colleges made their own decisions about such issues as when testing would take place (in relation to the beginning of instruction); which test would be administered to an examinee; and what criteria would be used in determining placement in a course. Thus, the results reported here represented the experience of a number of test users under the variety of conditions found in actual practice, rather than the outcome of a well-controlled experimental study. Fifty colleges and universities took part in the study—38 two-year colleges and 12 four-year institutions. Each student had a score on at least one module of ACCUPLACER and a placement and grade in one course. About one-third of the records included the student's self-reported gender and ethnic group membership. Frequency distributions, means and standard deviations of test scores are presented in Table 7.

Table 7**. Frequency Distributions of ACCUPLACER Scores Used in Validity Studies**

Scores	College-Level Mathematics	Elementary Algebra	Arithmetic	Reading Comprehension	Sentence Skills
110.001-120	11	321	255	274	976
100.001-110	31	359	408	1002	1364
90.001-100	57	413	356	1397	1273
80.001-90	101	555	468	1675	1510
70.001-80	169	516	527	1605	1200
60.001-70	254	518	531	1169	736
50.001-60	349	682	629	792	773
40.001-50	449	846	754	616	543
30.001-40	799	1675	993	422	417
20.001-30	1857	2243	1166	116	95
0-20	1145	8	27	13	2
N	5222	8136	6114	9081	8889
Mean	34.68	52.06	57.67	76.88	81.79
S.D**.**	19.15	27.74	27.80	20.95	23.12

Note. From *ACCUPLACER Online Technical Manual* (p. 64), by College Board, 2003, New York: College Board.

Correlation Results

Tables 8, 9, 10, 11 and 12 present analyses of the relationship of test scores with grades for Arithmetic, Elementary Algebra and College-Level Mathematics tests, respectively. The same organization was used in each table. For each course level examined, the correlation (merging across colleges the data from all students), the number of colleges (n) whose students provided data, the number of students (N) on whom the coefficient was based and the sample means and standard deviations of the scores and grades were presented. Each within-discipline combination of scores and grades for which at least 30 cases were available is included in the tables.

Next, the regression coefficients for predicting the grade from the test score was given, again, based on data merged across all colleges. (The coefficients a and b were entered into the regression equation, $Y = a + bX$, where X was the test score and Y was the predicted grade.) Below this was given the median correlation obtained from analyses within individual colleges, utilizing data from each institution for which at least 30 cases were available for the test-course combination, and then the institution-by-institution correlations. Note that the columns of individual institution results are independent of one another; for example, the first entry in one column might or might not represent data from the college that provided the first entry in the next column (College Board, 2003).

The analyses for individual institutions generally included the majority of the available cases, but an appreciable number of students come from institutions providing smaller numbers of cases. The overall coefficients obtained by merging data across institutions was similar to the median results obtained in the institution-by-institution analyses; the magnitude of the difference between comparable coefficients was typically small, and neither set showed consistently higher values than the other.

It should be noted that these coefficients were based on situations in which the test scores were used in placing students into courses. Thus, there was generally some restriction in the range of scores--sometimes rather severe restriction--as compared to that for all students who took one of the tests, and the coefficients underestimate the magnitude of the relations that would be found if the scores were not used in placement.

Arithmetic test scores had overall correlations between .31 and .38 with grades in General Mathematics, Arithmetic, Elementary Algebra and Intermediate Algebra courses

(see Table 8). The median correlations within colleges between Arithmetic test scores and those same courses ranged from .19 to .39 (see Table 9) (College Board, 2003).

The Elementary Algebra test scores across institutions had a median correlation of .19 with grades in Elementary Algebra courses (see Table 10). This coefficient reflected a substantial restriction in range due to the use of the test in placement in those courses; the standard deviation of test scores contributing to each coefficient was about 14.8 (see Table 10), compared with one of 27.7 for all students taking the test (see Table 7). Those taking this test and placing in more advanced courses constituted more proficient but less restricted samples; the mean score range from about 60 for Intermediate Algebra, 86 for College Algebra and 87 for Pre-calculus, to about 103 for Calculus. Overall, correlations of test scores with grades in those courses range from .19 to .38 (see Table 10) (College Board, 2003).

The College-Level Mathematics (CLM) test was intended to place students in courses in Intermediate Algebra, College Algebra, Pre-calculus and Calculus. The overall correlation of CLM test scores with grades falls in the range from .32 to .49 for those courses (see Table 11). The median within-college CLM test score-course grade correlation for those same courses ranged from .25 to .53 (see Table 12) (College Board, 2003).

Table 8. **Correlations of Arithmetic Scores with Grades in Mathematics Courses**

	Course			
	General Mathematics	Arithmetic	Elementary Algebra	Intermediate Algebra
Correlation	.38	.31	.33	.38
N of Colleges	18	19	20	21
N of Students	263	1118	890	464
Score Mean	64.27	40.05	62.12	79.36
Score S.D	25.88	16.61	23.01	22.76
Grade Mean	5.31	5.03	4.51	4.64
Grade S.D.	4.16	4.28	4.40	4.55
Regression a	2.5544	2.2593	1.5162	1.5902
Regression b	0.0548	0.0477	0.0512	0.0605

Note. From *ACCUPLACER Online Technical Manual* (p. 68), by College Board, 2003, New York: College Board.

Table 9. **Results for Individual Colleges - Arithmetic**

Median	.25		.31		.27		.39		.19	
College										
	N	**r**	**N**	**r**	**N**	**r**	**N**	**r**	**N**	**R**
I	39	.26	33	.56	73	.35	76	.61	66	.31
II	49	-.05	74	.18	54	.17	229	.21	66	.25
III	33	.25	121	.37	85	.32	52	.39	156	.13
IV	33	.54	230	.30	72	.55			65	.14
V			81	.47	125	.28				
VI			308	.32	146	.08				
VII			39	.53	37	.02				
VIII			55	.15	141	.26				
IX			32	.11						
X			104	.23						

Note. From *ACCUPLACER Online Technical Manual* (p. 68), by College Board, 2003, New York: College Board.

Table 10. **Correlations of Elementary Algebra Scores with Grades in Mathematics Courses**

	Course				
	Elementary Algebra	Intermediate Algebra	College Algebra	Pre-calculus	Calculus
Correlation	.19	.33	.26	.38	.31
N of Colleges	21	25	25	24	20
N of Students	1360	1040	866	238	168
Score Mean	39.39	60.19	86.17	86.82	103.29
Score S.D	14.80	23.37	18.80	24.67	16.56
Grade Mean	4.71	4.71	5.02	5.24	5.70
Grade S.D.	4.44	4.36	4.33	4.40	4.00
Regression a	2.9328	2.3843	3.0474	2.8463	2.8764
Regression b	0.0295	0.0518	0.0402	0.0569	0.0441

Note. From *ACCUPLACER Online Technical Manual* (p. 69), by College Board, 2003, New York: College Board.

Table 11. **Correlations of College-Level Mathematics Scores with Grades in Mathematics Courses**

	Course				
	Elementary Algebra	Intermediate Algebra	College Algebra	Pre-calculus	Calculus
Correlation	.34	.34	.32	.33	.49
N of Colleges	20	27	30	26	25
N of Students	413	711	863	250	747
Score Mean	21.22	29.13	36.07	49.28	61.19
Score S.D	4.36	10.66	13.62	19.22	21.08
Grade Mean	4.16	5.67	5.09	5.91	4.98
Grade S.D.	4.10	4.28	4.33	4.25	3.99
Regression a	1.7663	2.3527	2.6734	3.3004	1.6092
Regression b	0.0779	0.0786	0.0711	0.0724	0.1027

Note. From *ACCUPLACER Online Technical Manual* (p. 70), by College Board, 2003, New York: College Board.

Table 12. **Results for Individual Colleges – College Level Mathematics**

Median	.25		.34		.35		-		.53	
College	**N**	**r**	**N**	**r**	**N**	**r**	**N**	**r**	**N**	**r**
I	38	.05	96	.33	91	.51			.3	.37
II	30	.20	34	.47	37	.25			241	.60
III	66	.25	86	.40	64	.19			260	.57
IV	91	.56	66	.37	32	.43			48	.49
V	77	.25	56	.11	37	.35				
VI			76	.35	62	.42				
VII			114	.32	54	.22				
VIII			60	.32	67	.12				
IX					33	.18				
X					151	.42				
XI					71	.55				

Note. From *ACCUPLACER Online Technical Manual* (p. 70), by College Board, 2003, New York: College Board.

OTHER ACCUPLACER VALIDITY STUDIES

In addition to the multi-institution research conducted by the College Board, validity studies had been conducted on ACCUPLACER in a specific institution or at a group of institutions, such as the state or county levels. The exact number of ACCUPLACER validity studies conducted at institutions was not known, because not all institutions report their results to the College Board. However, several institutions acquired assistance from the College Board in conducting their studies or sent a report to the Board when it was completed (College Board, 2003).

Table 13 lists seven ACCUPLACER validity studies conducted since the College Board's 50th-institution study. For each study, a citation, the specific subtest studied, overall sample and abbreviated conclusions were presented. One or more institutions conducted four of the studies; the College Board in cooperation conducted the other three with one or more institutions. The studies were best described as concurrent validity studies (2), predictive validity studies (1) or both (4) (College Board, 2003).

An inspection of the results in Table 13 indicated that when ACCUPLACER scores were correlated with scores from similar test, the concurrent validity coefficients tended to be high (i.e., above .60). The correlations of ACCUPLACER scores with overall GPA were also high (.41 to .84). Three studies gathered data on placement accuracy using either teacher's ratings or grades as the validation criterion. In those studies, placement decisions based on ACCUPLACER scores agreed with placements made using the validity criterion 69% - 90% of the time (College Board, 2003).

Table 13. **Summary of Selected ACCUPLACER Validity Studies**

Validity Study	Type(s) of Validity	Location	Tests Studied	Overall Sample Size	Results and Conclusions
Napoli & Wortman (1995)	Predictive Validity	Suffolk, CC (NY)	RC	16,000	RC&GPA r = .41; RC & Psych r = .52; Placement agreement range = 69-77%
Brookdale CC (1996, February)	Concurrent, Predictive	Lincroft, New Jersey	AR, EA, RC, SS	976	Concurrent r's w/ NJCBST range = .74-.90; Placement accuracies range from 74%-93%
Cole, Muenz, & Bates (1998)	Predictive validity, DPV	2 Midwest CCs	RC	4,298	RC&GPA r =.84; magnitude of PV increased with age of cohort.
Napoli (1998)	Concurrent	Suffolk, CC (NY)	AR, EA	642	AR.&EA r with local math test =.33-.45;
College Board (1999, May)	Concurrent	Tennessee	AR, EA, RC	3,800	Concurrent r's range =.68-.71 (.74-.80 after correction for range restriction); Average placement agreement = 64%
College Board (1999, November)	Predictive, Consequential	California	AR, EA, CLM, RC, SS, LOEP	29,000	Average placement accuracies: RC=79%; RC w/ SS = 86%; AR w/ EA = 80%; CLM=90%
College Board (2000, June)	Concurrent; standard setting	National Louis University	AR, EA, RC, WP	1,450	RC&DRP r=.80; WP&DRP r =.41; AR r range =.18-.35; EA r range =.25-.40

Note: AR=Arithmetic, EA=Elementary Algebra, CLM=College Level Math, LOEP=Levels of English Proficiency, RC=Reading Comprehension, SS=Sentence Skills, WP= WritePlacer Plus; CC=Community College, DPV=Differential Predictive Validity.

Note. From *ACCUPLACER Online Technical Manual* (p. 85), by College Board, 2003, New York: College Board.

SUMMARY

In reviewing the literature related to the problem of comparing WorkKeys skill level scores and COMPASS/ESL placement score for placement into college level mathematics, Chapter II described the construct validity of tests used for academic placement into mathematics courses and for pre-employment screening of workplace skills. Though student success has traditionally been determined by factors that were at best difficult to quantify, course placement based on the results of an examination had been the standard procedure at most two-year colleges for over two decades. Little to no data existed to support the notion that course placement based on the results of a test had increased student performance. One of the more popular tests used for course placement was the COMPASS/ESL computer adaptive test. Results obtained by the use of COMPASS/ESL have been compared with other standardized tests with mixed results, supporting the conclusion that tests used for educational decisions such as placement all must measure the same things, and they must measure what the curriculum deals with. Wherein the assessment component of WorkKeys is specifically designed to evaluate workplace skills there had been no effort to use WorkKeys as the assessment tool for placement into technical programs that were specifically designed to provide technical and workplace skills for people who were entering the skilled workplace. There was no existing published research data that compares COMPASS/ESL and WorkKeys results in an effort to determine the feasibility of using WorkKeys to place new students into college level mathematics courses. Chapter III will focus on the methods and procedures used to gather and analyze the data used in this study.

CHAPTER III

METHODS AND PROCEDURES

This chapter outlines the methods and procedures used to conduct this study. This was a quasi-experimental study. In this chapter the population, research variables, instrument design, methods of data collection and statistical analysis will be discussed. The chapter concludes with a summary of the methods and procedures.

POPULATION

The population of this study consisted of AREVA-NP and Tyco Electronics employees majoring in curricula of studies for the AAS in Nuclear Support Technology and AAS in Electronics Technology at Central Virginia Community College in Lynchburg, VA. Forty-eight students had enrolled in the programs that had started in the fall academic year of 2002. Additionally, each student had completed a mathematics course that had been recommended based on COMPASS/ESL placement scores. The two cohorts were made up of 31 Nuclear Support and 17 Electronics Technologies students.

RESEARCH VARIABLES

The independent variable in this study was the Applied Mathematics skill level score. The dependent variable was the COMPASS/ESL mathematics placement test score. Students from both groups including Nuclear and Electronics Technology had a WorkKeys Applied Mathematics skill level score and a COMPASS/ESL placement test score.

INSTRUMENT DESIGN

The WorkKeys Applied Mathematics test assessed generic workplace skills developed by ACT and were used to screen all Nuclear and Electronics Technicians.

These WorkKeys tests used the parallel forms method to insure reliability. Each test was criterion-referenced with respect to its content domain (i.e., each individual's skills were measured with respect to the content being assessed and independent of the performance of other examinees). The Applied Mathematics assessment was just one of the types of tests selected based on the job profile (job analysis) results. The job profile included the minimum Applied Mathematics skill level required for job entry level (ACT, 2007).

The Applied Mathematics assessment presented workplace situations and problems for examinees to either respond to, solve or both. Within any given assessment, the situations represented many different jobs, occupations and workplaces. The Applied Mathematics assessment was presented in booklet format with multiple-choice questions. The Applied Mathematics assessment was constructed with a number of different levels and each successive level was more complex that the previous one (ACT, 2007).

Developed by ACT the COMPASS/ESL assessments were computer-adapted placement tests designed to assist colleges in placing students into appropriate introductory or development (remedial) courses. The COMPASS/ESL test resulted in five possible placement scores in the mathematics domains, including Numerical Skills/Pre-algebra, Algebra, College Algebra, Trigonometry and Geometry. Each of the five content domains contained a pool of about 200 or more five-option multiple-choice items. The five domains were roughly hierarchical (ACT, 2006).

METHODS OF DATA COLLECTION

The researcher utilized existing data obtained from student records. The Express Score data base was used to generate Examinee Roster Reports that listed the WorkKeys scores for each, while the COMPASS scores were retrieved from CVCC's data base

(People Soft) for each student. A table was designed that contained the WorkKeys skill level scores and COMPASS/ESL placement scores for each student.

Placement decisions were typically made using placement variables where a student was required to obtain a certain minimum value on the placement variable or variables to be placed into the standard level course. The minimum value that a student must attain to be placed into the standard course could involve a single value on the placement variable(s) (e.g., a cutoff score) or a range of scores or decision zone. Cutoff scores of decision zones were typically tied to a student's probability of success in the standard course. Students who scored at or above the cutoff score (students whose estimated probability of success equals or exceeds a particular value) were placed into the standard course. Students who scored below the cutoff score (students with a lower probability of success) were placed into the remedial course.

STATISTICAL ANALYSIS

After the data were collected, a Pearson's *r* test was conducted in an effort to determine if there was a statistical correlation in the linear relationship between WorkKeys Applied Mathematics assessment skill level scores and mathematics courses that had been recommended for the student based on the COMPASS/ESL placement scores. WorkKeys skill level scores and the COMPASS/ESL scores of the 48 Nuclear and Electronics Technicians were the only two data sets that were analyzed for this study.

SUMMARY

This chapter provided information on the methods and procedures used to gather data necessary to conduct the research. The population and the instrument design were

identified. A detailed explanation of how the data were collected and analyzed was provided. Chapter IV describes the findings and analyzes the data collected.

CHAPTER IV

FINDINGS

The purpose of this study was to determine the relationship between the WorkKeys Applied Mathematics skill level scores and COMPASS/ESL Mathematics placement scores as a predictor for placement into college level mathematics. This chapter will include an overview of the data that were collected, as well as a table that graphically represents the information gathered. A narrative summary of the findings that resulted from the collected data will also be included in this chapter.

RESEARCH PARTICIPANTS

The subjects of this study included 48 new hires of AREVA-NP and Tyco Electronic in Lynchburg, VA. The data were collected during the summer 2008 semester for the academic years of 2002-2006. WorkKeys was used as part of the hiring process for all new employees, so all of the 48 participants had WorkKeys Applied Mathematics skill level scores. Additionally, they had taken the COMPASS/ESL placement test for Mathematics which was part of the admissions process at Central Virginia Community College.

RESULTS

The mean WorkKeys Applied Mathematics skill level score for all subjects studied was 4.6, while the mean course placement score was 35.2. WorkKeys skill level scores ranged from 2 to 7 and COMPASS/ESL mathematics course placement scores ranged from 15 to 93. These data are graphically displayed in Table 14.

Table 14. **WorkKeys Applied Mathematics and COMPASS/ESL Mathematics Scores**

Subject #	WorkKeys Applied Skill Level Score	COMPASS/ESL Mathematics Scores
1	5	51
2	3	32
3	3	27
4	3	29
5	3	58
6	3	15
7	2	16
8	4	21
9	3	19
10	3	18
11	2	46
12	4	45
13	4	38
14	4	20
15	4	32
16	3	16
17	4	17
18	3	17
19	5	32
20	4	53
21	2	33
22	3	16
23	5	61
24	6	44
25	7	63
26	7	66
27	7	64
28	5	90
29	7	68
30	7	78
31	6	21
32	6	17
33	6	16
34	6	20
35	5	15
36	6	18
37	5	15
38	5	16
39	4	21
40	4	17
41	5	15
42	6	16
43	5	15
44	6	18
45	6	50
46	5	37
47	6	67
48	6	93
MEAN	4.6	35.2
RANGE	2 – 7	15 – 93

Mathematics scores for subjects in this study were based on COMPASS/ESL placement scores and WorkKeys Applied Mathematics. If COMPASS/ESL was an appropriate predictor for course placement, and if a strong correlation exists between WorkKeys skill level scores and COMPASS/ESL placement scores, it may indicate the academic course a student should be placed. Thus, if there is a strong relationship between the COMPASS/ESL placement scores and WorkKeys skill level scores, this may support the use of WorkKeys for placement purposes. In this study a Pearson's *r* was used to analyze the data that were collected and displayed in Table 14, the *r*-value was +.40.

SUMMARY

The purpose of this study was to determine the relationship between the WorkKeys Applied Mathematics skill level scores and COMPASS/ESL Mathematics placement scores as a predictor for placement into college level mathematics. It was hypothesized that there would be a strong correlation between WorkKeys skill level scores and COMPASS/ESL mathematics placement scores used to place students into mathematics courses. This research revealed that the mean WorkKeys skill level score (4.6) was lower than the mean COMPASS/ESL placement score (35.2). The Pearson's *r*-value was +.40. Chapter V will provide the Summary, Conclusions and Recommendations for this study.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter will provide a summary of the research study that was conducted in an effort to determine the relationship between WorkKeys Applied Mathematics skill level scores and COMPASS/ESL Mathematics placement scores as predictors for academic placement into college level mathematics courses. This chapter will focus first on a summary of this research study. Then, conclusions will be presented, based on the data that were collected and the finding that were present. Finally, the researcher provides recommendations based on the results of the study and makes recommendations for future studies.

SUMMARY

The purpose of this study was to determine the relationship between the WorkKeys Applied Mathematics skill level scores and COMPASS/ESL Mathematics placement scores as predictors for placement into college level mathematics. To guide a solution to this problem, the following hypothesis was developed:

H_1: WorkKeys Applied Mathematics skill level scores on the WorkKeys test will be a successful predictor of achievement on the COMPASS/ESL mathematics placement test.

This study arose as a result of an attempt to use the WorkKeys Applied Mathematics skill level score for placement into college level mathematics courses. Consequently, if there was a strong relationship between the WorkKeys Applied Mathematics skill level score and the COMPASS/ESL mathematics placement score it

should be strongly considered when making placement decisions for students at CVCC in Lynchburg, VA.

The limitations of this study included the following:

1. This research was limited to a selected group of subjects: Nuclear and Electronics Technicians from two companies within the service area for CVCC.
2. Only employers who utilized WorkKeys profiles and assessment results in the hiring process were included.

The population utilized in this study included 48 students employed with AREVA-NP and Tyco Electronics. These employees were majoring in curricula of studies for the AAS in Nuclear Support Technology or AAS in Electronics Technology for the academic years from 2002-2006 at CVCC.

The researcher compiled the WorkKeys Applied Mathematics skill level scores and COMPASS/ESL mathematics placement scores using data extracted from the Express Score and People Soft databases. A Pearson's *r* statistical analysis was conducted in an effort to determine if there was a statistical correlation in the linear relationship between WorkKeys Applied Mathematics skill level scores and COMPASS/ESL mathematics placement scores.

CONCLUSIONS

To guide a solution to this problem, the following hypothesis was developed:

H_1: WorkKeys Applied Mathematics skill level scores on the WorkKeys test will be a successful predictor of achievement on the COMPASS/ESL mathematics placement test. The calculated Pearson's *r* analysis ($r = +.40$) resulted in accepting the hypothesis at

the p>.01 = .372 level of significance. There was a low level of magnitude (.20 - .40) between WorkKeys skill levels scores and COMPASS/ESL placement test scores. Thus, the relationship was too weak to support the use of WorkKeys skill level scores as a predictor of achievement on the COMPASS/ESL placement tests used for the placement of students into standard mathematics courses.

RECOMMENDATIONS

The results reached in this study were obtained from data that were gathered from existing records at Central Virginia Community College in Lynchburg, Virginia. Since it is likely that placement decisions vary from institution to institution, these results should be verified by replicating this study using data from other colleges. Further studies should be done to determine if there is a significant relationship between WorkKeys Business Writing skill level scores and the COMPASS/ESL Writing placement test.

If WorkKeys is accepted by so many industries as a tool for determining workplace skills and if the objective of career and technical education was to prepare those students for practical skills needed in the workplace, then research should be done to determine why there was not a strong correlation between WorkKeys skill level scores and COMPASS/ESL placement tests scores. Given that COMPASS/ESL mathematics test results are used for placing students into a core curriculum course such as mathematics for career and technical education programs in Central Virginia.

The alignment of career and technical education programs with the needs of the industries those programs support is a critical concern. They should focus on providing an experience that is close to the "real world" as possible and should teach students the skills that are sought by industry. Finally, could it be that the career studies certificate

programs at CVCC still have a ways to go to adequately prepare students to fully meet the needs of industry? The gap between what the curricula aims to teach its students and what the workplace is seeking from its employees is still too wide. More needs to be done to bridge the divide between what students in the classroom are learning and what skills are sought by industry.

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