COMPARATIVE VALIDITY OF THE DESCRIPTIVE TESTS OF MATHEMATICAL SKILLS (DTMS) AND SAT - MATHEMATICS (SAT-M) FOR PREDICTING PERFORMANCE IN FRESHMAN COLLEGE MATHEMATICS COURSES: PREFATORY REPORT.

M. Padraig M. M. McLoughlin

Morehouse College

pmclough@morehouse.edu

Dontrell A. Bluford

Morehouse College

blumagic29@yahoo.com

ABSTRACT

COMPARATIVE VALIDITY OF THE DESCRIPTIVE TESTS OF MATHEMATICAL SKILLS (DTMS)
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M. PADRAIG M. M. MCLOUGHLIN & DONTRELL A. BLUFORD
MOREHOUSE COLLEGE

This study investigated the predictive validity of the Descriptive Tests of Mathematical Skills (DTMS) and the SAT –Mathematics (SAT-M) tests as placement tools for entering students in a small, liberal arts, historically black institution (HBI) using regression analysis. The placement schema is four-tiered: for a remedial algebra course, college algebra course, pre-calculus course, and a first calculus course. Low psychometric indices were found between score earned on the Elementary Algebra Skills (EAS), Intermediate Algebra Skills (IAS), and Calculus Readiness: Functions and Graphs (CR) of the DTMS and grade earned in College Algebra, Pre-calculus, and Calculus I, respectively, and between score earned on the SAT-M and grade earned in College Algebra, Pre-calculus, and Calculus I.

Define E denote the score earned on the EAS, I the score earned on the IAS, R the score earned on the CR, S the score earned on the SAT-M, B the grade earned in the Basic Mathematics course, A the grade earned in the College Algebra course, P the grade earned in the Pre-calculus class, and C the grade earned in the Calculus I class. The models for the DTMS produced were as follows: $\hat{A} = 1.504 + 0.039E$ for the EAS of the DTMS; $\hat{P} = 1.030 + 0.084I$ for the IAS of the DTMS; and, $\hat{C} = 1.670 + 0.050R$ for the CR of the DTMS; whereas, the models for the SAT-M produced were: $\hat{A} = 0.241 + 0.004S$; $\hat{P} = 0.695 + 0.003S$; $\hat{C} = -0.519 + 0.005S$.

Perhaps the most interesting component of the study was not the regression equations, correlations, or any other parametric statistical portion of the study but the effect of the change of policy on the placement schema at the college. If placement decision were based on scores of SAT-M rather than on scores earned on the DTMS, there seems to be a shift of students such that less were placed in the remedial class and more into the courses that allowed a student to earn college credit and satisfy core curriculum requirements for mathematics.

The paper ends with recommendations for further research on minimum competence testing and placement and notes the follow-up studies to this study that will be done by the researchers.

INTRODUCTION

The purpose of the study was to add to the body of evidence regarding the predictive validity of three tests of the Descriptive Tests of Mathematical Skills (DTMS), the Elementary Algebra Skills (EAS) test, Intermediate Algebra Skills (IAS) test, and Calculus Readiness: Functions and Graphs (CR) test or of the SAT - Mathematics (SAT–M) as tools used to place students in freshman level mathematics courses. This study investigated the relationship between students' scores earned on the EAS, IAS, and CR of the DTMS and the SAT–M and grades earned in a College Algebra, Pre-calculus, and Calculus I class (respectively) at a four year, private, liberal arts, and historically black college in the southern United States. This is an attempt to estimate the predictive validity of the EAS of the DTMS versus the SAT–M and grades earned in the College Algebra course, the IAS of the DTMS versus the SAT–M and grades earned in the Pre-calculus course, and the CR of the DTMS versus the SAT–M and grades earned in the Calculus I. The student body at the four year, private, liberal arts, and historically black college was all male of which approximately 97.359%[1] were African-American. The overall enrolment at the college was approximately 2,800 students.

At the liberal arts college, the mathematics department's placement was based on the results of a student's performance on three (EAS, IAS, and CR) of the four components of the DTMS through 1998. In 1999, the placement scheme was changed to placement in freshman mathematics courses based on results from the SAT-M. The policy was changed through the Office of Academic Affairs at the college; but, faculty in the mathematics department reported anecdotal evidence to suggest that more students were misplaced (mostly at a higher level than prepared for) using the scheme of the SAT-M rather than the scheme of the DTMS. The college requires all students compleat a minimum of six credit hours of course-work in mathematics at the 100-level or above (there is a more stringent requirement for students majoring in the 'hard' sciences than the social sciences or humanities).

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[1] Note: all constants reported are precise to two significant figures.

The Descriptive Tests of Mathematical Skills (DTMS) of the College Board (Educational Testing Service, 1979; revised, 1988) includes four tests: Basic Arithmetic Skills (BAS), Elementary Algebra Skills (EAS), Intermediate Algebra Skills (IAS), and Calculus Readiness: Functions and Graphs (CR). Each is in a four-option multiple choice format, and the maximum testing time for each is 30 minutes. The BAS and EAS tests are 35-item tests. The IAS and CR are 30-item tests. These tests can be used separately or in any combination to conduct minimum mathematics competency placement of students for many types of courses including, but not limited to, freshman level mathematics courses.

The 35 question EAS is comprised of nine questions covering operations with real numbers, nine questions covering operations with basic algebraic expressions, eight questions covering solutions of basic equations and inequalities, and nine questions covering applications of the aforementioned. The 30 question IAS is comprised of seven questions covering algebraic operations, eight questions covering solutions of equations and inequalities, eight questions covering geometry, and seven questions covering applications in statistics, probability, and data interpretation. The 30 question CR is comprised of eight questions covering algebraic functions, nine questions covering exponential and logarithmic functions, and thirteen questions covering trigonometric functions (College Entrance Examination Board, 1989; Educational Testing Service, 1988).

The SAT – Mathematics (SAT-M) is in a four-option or five-option multiple choice format 60 question test administered in three part (two 30 minute parts and one 15 minute part) and is comprised of approximately three-tenths of the 60 questions cover Arithmetic (Number and Operations), approximately three-tenths of the 60 questions covers Algebra and Functions, approximately three-tenths of the 60 questions cover Geometry and Measurement, and approximately one-tenth covers Data Analysis, Statistics, and Probability.

There is scant research regarding the use of the DTMS in minimum competency placement testing programmes designed to validate the mathematical skills of entering freshmen students into college. Many of the instruments used for measuring mathematical skills of the entering freshmen are locally developed, but a few are standardised tests (most

oft the BAS, EAS, IAS, or CR of the DTMS, the ACT-M (American College Testing [Programme] Mathematics), the SAT-M, or the SATII-M (SATII Mathematics).

Prior researchers estimated the predictive validity of the Elementary Algebra Skills (EAS) test of the DTMS, other tests of the DTMS, or combinations of the aforementioned. For example, Bridgeman (1980) found the DTMS was "predictive of end of course grades when administered at the beginning of the course" (page 82). Correlation between the score earned on the EAS and grade in a college algebra course ranged from a low of 0.30 to a high of 0.58 for 10 colleges or university with sample sizes ranging from 16 to 99 subjects. Bridgeman (1982) compared the validity of the EAS and IAS to the Scholastic Aptitude Test - Mathematics (SAT-M) and found the EAS or IAS a better predictor of performance for a remedial algebra course than the SAT-M, whereas the EAS, IAS, and SAT-M performed about equally well for predicting performance in a calculus course. He found psychometric indices of 0.46 and 0.47 between the grade earned in an Elementary Algebra course and the score earned on the EAS based on 73 subjects at a small private 2-year college and on 198 subjects at a large public 4-year college, respectively. Suddick and Collins (1985) found a test-retest reliability coefficient of 0.72 for the EAS of the DTMS for older, adult transfer students using a small sample. Suddick and Collins (1982) also investigated the predictive validity of the EAS and IAS for grades earned in a calculus or statistics course for older upper division students. They found that students who passed either the EAS or IAS performed significantly better than did those who failed the DTMS, were remediated, and then earned a grade in either the statistics or calculus course. Suddick and Collins (1984) further investigated the predictive validity of the EAS for grades earned in a calculus course for older Master's level students. Suddick and Vaccarro (1983) discussed the issues involved in minimum competency testing using the BAS for business students. Dwinell (1985) investigated the predictive validity of the BAS and EAS to estimate exit from a remedial mathematics course for students who earned failing scores on the Basic Skills Examination - Mathematics test and found the EAS contributed the "most variance to an estimate of prediction of exit from [remedial] math courses" (page 12).

Nonetheless, all of the aforementioned research reports used the original version of the DTMS as an instrument and only the original Bridgeman studies (1980, 1981, and 1982) considered the CR of the DTMS. The DTMS was revised in 1988, and very little research exists that investigated the predictive validity of the revised DTMS. Meyer, Woodard, and Suddick (1994) investigated the predictive validity of the BAS and EAS (revised DTMS) for grades earned in an advanced mathematics concepts and structure course for upper-division elementary education students and found a moderate predictive validity coefficient (R = 0.49) using a small sample.

McLoughlin (1999, 2000) found that students who passed the EAS, IAS, and CR of the DTMS did have a significantly higher average level of performance in College Algebra, Pre-calculus, and Calculus I, respectively, than did the students who did not have the prerequisite minimum competency skills in mathematics as measured by the EAS, IAS, or CR of the DTMS but were successfully remediated. He also opined that the difference between the grades earned in each of the respective courses was practically significant. His findings corresponded with the findings of Bridgeman (1980, 1981, and 1982) for the original version of the DTMS.

Bridgeman and Wendler (1989) investigated the predictive validity of the SAT- M by collecting grades from freshman mathematics courses at 10 colleges (3,499 students). They compared the SAT-M to tests that were specifically designed for placement purposes and found the SAT-M score was a relatively poor predictor of grades in most courses. However, they found that the SAT-M significantly improved predictions for freshman mathematics course grades (especially for calculus courses) over using just high school grade point average (GPA).

Notwithstanding, all of the studies heretofore mentioned have been conducted at colleges or universities that are not analogous to the college where the data was collected in this study.[2] In addition, some of the studies did not account for a percentage of African-Americans in the sample, while others had over 90% White subjects; ergo, the possibility exists that the predictive models from those studies may not generalise to the population

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[2] It should be noted that the DTMS was piloted at the college where the data was collected for this study in the late 1970s and a member of the faculty at said college (no longer a member of the faculty) was on the team that designed the DTMS.

studied in this project. Notwithstanding, this research assumes that the studies previously noted are valid and, therefore, the research question in this study includes whether or not the models from previous studies of the EAS, IAS, and CR of the DTMS and the SAT-M are comparable to the model generated in this study.

METHODS

This paper estimates predictive validity (overall significance level of 0.05) to model prediction of grade earned in the respective college mathematics course using the score earned on the EAS, IAS, CR, and SAT-M. Each of the EAS, IAS, and CR were compared to the placement method used for the SAT-M. The researchers used regression to analyse the data.

The researchers used regression analysis ($\alpha = 0.05$) to analyse the difference between the means of the grades earned by students in the course he was placed of those who passed and those who failed the part of the DTMS but were placed in the course previous and then took the course the following semestre to build a predictive model. It was determined a stable and interpretable model was produced that only used the score earned on the EAS, IAS, CR, or SAT-M as a regressor with the grade earned in the respective freshman-level course (College Algebra, Pre-calculus, or Calculus I) as the measured response rather than for each part of the DTMS scores or SAT-M along with a dummy variable indicating pass or fail status and an interaction term as the regressors.

A small pilot study (n = 47) was conducted in the spring of 1997 using scores earned on the EAS, IAS, and CR of the DTMS and grade earned in College Algebra, Pre-calculus, and Calculus I from fall of 1993 through fall of 1994 for a random sample of entering freshmen in the fall of 1993 to 1) determine an adequate period of grade records needed to ensure that enough time was allowed for those who placed in the remedial mathematics course to successfully compleat the course and be able to attempt to earn a grade in College Algebra (to be discussed in the next paragraph); and, 2) test underlying statistical assumptions (normally independent distribution, underlying continuity, linearity, and homoscedasity) for conducting a regression analysis. The underlying assumptions were found to be tenable based on the results of the pilot study.

A record of performance on the EAS, IAS, and CR of the DTMS for the 186 subjects was obtained as well a record of performance on the SAT–M. The scores earned on the EAS were integer values from 0 to 38, inclusive; scores earned on the IAS or CR were integer values from 0 to 30, inclusive, but were considered continuous for the study. The scores earned on the SAT-M were integer values from 200 to 800 (multiples of ten), but were considered continuous for the study. Also, mathematics departmental records of grades earned by students in the freshman-level courses for the period of fall 1998 through spring 2000, inclusive, were used. The grade records period of fall 1998 through spring 2000 was used because by using these parametres maximisation of the usable number of records in the study was possible. Some students defer enrolling in their mathematics courses at the college for well over a year, therefore, 1998 - 2000 covers a reasonable time for entering freshman-level courses and earning a grade and yet restricts the time for entering freshman-level courses so that the predictive power of the DTMS was not compromised.

The grade earned in freshman-level courses is based on the 4-point plus - minus scale. The grade was considered a continuous variable. Only the grade a subject earned on his first attempt in a freshman-level course was considered. The definition of earned grade used in this study was an "A+" (4.0) to an "F" (0.0).[3] The grades "W," "WP," and "WF" which signify withdrawal, withdrawal passing, and withdrawal failing, respectively, were not considered as an earned grade in the course. Thus, if a "W" was assigned for subject X, for example, in the fall of 1998, but he earned a "D" in the spring of 1999, then a 1.0 (the numeric equivalent for a "D") was recorded for Subject X. The grades were recorded twice independently, then the two files were compared with the departmental records, and a final data set was thus produced.

Cut scores for the three DTMS tests were as follows: 24.5 for the EAS, 20.5 for the IAS, and 20.5 for the CR. Ergo, a student who selects 24 correct answers or less on the EAS is required to enrol in a 0 semestre credit hour remedial mathematics course (which is a review of high school algebra). The student was required to earn a "C" or better in the

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[3] An "A+" is recorded as 4.0, an "A" is recorded as 4.0, a "A-" is recorded as 3.7, a "B+" is recorded as 3.3, a "B" is recorded as 3.0, a "B-" is recorded as 2.7, a "C+" is recorded as 2.3, a "C" is recorded as 2.0, a "C-"

course in order to enrol in College Algebra. A student who selects 25 correct answers or more was permitted to enrol in College Algebra. Further, if a student selects 20 correct answers or less on the IAS, then he was required to enrol in College Algebra, but a student who selects 21 correct answers or more on the IAS was permitted to enrol in Pre-calculus, and if he selects 21 correct answers or more on the CR test, he was permitted to enrol in Calculus I.

The decision schema adopted by the college in 1999 for use with the SAT-M is as follows: cut scores for the SAT-M were as follows: 415, 535, and 595. Hence, a student whose score is less than 410 is required to enrol in a 0 semestre credit hour remedial mathematics course; a student whose score is greater than or equal to 420 but less than 540 is permitted to enrol in College Algebra; a student whose score is greater than or equal to 540 but less than 600 is permitted to enrol in Pre-calculus, and a student whose score is greater than or equal to 600 is permitted to enrol in Calculus I.

Simple regression analysis was performed to ascertain the validity of the placement model using the EAS, IAS, and CR of the DTMS for this population. The grades earned in the freshman-level courses were assumed independent. Residual analyses were performed which confirmed the tenability of the assumptions necessary for inference in regression analysis; namely, that the dependent variable, grade earned in the respective freshman-level course, was approximately normally distributed, the relationship between the independent and dependent variables was linear, and that there was homogeneity of variances.

The study was also to have included another component which has not been executed as of this time. SAT-M records for freshmen who entered the college in the fall of 1999 were to be used along with mathematics departmental records of grades earned by students in the freshman-level courses for the period of fall 1999 through spring 2001. A model was to be produced using SAT-M as a regressor with the grade earned in the respective freshman-level course (College Algebra, Pre-calculus, or Calculus I) as the measured response. This model was to be compared to the 1998 model for the SAT-M as well as for the DTMS for the 1998 data. However, the researchers have not gained access to the 1999 SAT-M data; thus, this study is a prefatory report. Therefore, herein for subjects and results

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is recorded as 1.7, a "D+" is recorded as 1.3, a "D" is recorded as 1.0, a "D-" is recorded as 0.7, and an "F" is

sections a detailed mention of the 1999 SAT-M portion of the study will not be included; but, in the discussion section the 1999 portion will be mentioned.

SUBJECTS AND SAMPLING TECHNIQUE

The subjects were a subset of the set of entering freshmen at four year, private, liberal arts, and historically black college in the fall of 1998. Approximately 97% of the entering freshmen of the class of 1998 were United States citizens, with the remainder from the Caribbean or Africa. The placement testing policy at the college required all entering freshmen to take three DTMS tests : EAS, IAS, and CR. Cut scores for the three DTMS tests were as follows: 24.5 for the EAS, 20.5 for the IAS, and 20.5 for the CR.

Hence, the subjects of the study are the subset (n = 186) of the entering freshmen (N = 599) who entered the college in the fall of 1998. All 599 entering freshmen took the three DTMS tests: EAS, IAS, and CR and the 186 subjects of this study were randomly selected from the 599 entering freshmen using a modified four stage systematic sampling design created by the primary author.

The systematic sampling procedure was as follows. For stage one, one hundred eighty-six numbers were pseudo-randomly selected from $\mathbb{N}_{599}$.[4] If the subject also reported SAT-M scores then the record was used. If not, then stage two was employed which started with selecting a pseudo-random number from $\mathbb{Z}_{10}\backslash\{0\}$.[5] If that record was not used before and also contained a reported SAT-M score, then it was used; if not, then stage three was employed which required selecting a pseudo-random number was used from $\mathbb{Z}_5\backslash\{0\}$.[6]

If that record was not used before and also contained a reported SAT-M score, then it was

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recorded as 0.0. The grades of "F+" and "F- " do not exist.

[4] $\mathbb{N}_{599} = \{x \mid x \in \mathbb{N} \wedge x < 600\}$.

[5] $\mathbb{Z}_{10}\backslash\{0\} = \{-10, -9, -8, -7, -6, -5, -4, -3, -2, -1, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10\}$.

used; if not, then stage four would be employed a pseudo-random number was used from $\mathbb{Z}_3\backslash\{0\}$.[7] The pseudo-random number tables were generated with SPSS 10.0 (without a

pre-set seed) and it should be noted that only through stage three of the sampling process was needed.

The result was four subsets were created composed of those who failed the EAS, IAS and CR (group 0, $n_0 = 46$); those who passed the EAS but failed the IAS and CR (group 1, $n_1 = 66$); those who passed the EAS and IAS but failed the CR (group 2, $n_2 = 38$); and, those who passed the EAS, IAS, and CR (group 3, $n_3 = 24$). Group 0 members were placed in the remedial Basic Mathematics course, Group 1 members were placed in College Algebra, Group 2 members were placed in Pre-calculus, and group 4 members were placed in Calculus I.

RESULTS

Let E denote the score earned on the EAS, I denote the score earned on the IAS, R denote the score earned on the CR, S denote the score earned on the SAT-M, B denote the grade earned in the Basic Mathematics course, A denote the grade earned in the College Algebra course, grade earned in the Pre-calculus class, and C denote the grade earned in the Calculus I class.

KR_{20} reliability of each of the tests of the DTMS were computed (such was not the case for the SAT-M since the item responses were not available). KR_{20} reliability of the EAS instrument was 0.8744; KR_{20} reliability of the IAS instrument was 0.8443; and, KR_{20} reliability of the CR instrument was 0.8769.

Descriptive statistics for each of the tests were computed for all entering freshmen in the fall of 1998 (N = 599). For the EAS, $\mu_E = 25.46$, $\sigma_E \approx 6.164$, minimum score 0, maximum score 35; for the IAS, $\mu_I = 17.51$, $\sigma_I \approx 5.571$, minimum score 0, maximum score 30; for the CR, $\mu_R = 12.61$, $\sigma_R \approx 6.589$, minimum score 0, maximum score 29; and, for the SAT-M ($N_S = 510$), $\mu_S = 524.71$, $\sigma_S \approx 85.15$, minimum score 350, maximum score 780.

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[6] $\mathbb{Z}_5\backslash\{0\} = \{-5, -4, -3, -2, -1, 1, 2, 3, 4, 5\}$.

The assumption of normality was tenable because the normal probability plot using jack-knife residuals for a linear model fitted to the data showed no obvious deviation from normalcy (see figure 1 which illustrates the EAS – CA relationship). The assumption of homogeneity of variances was tenable because analysis of predicted-A versus the jack-knife residual showed no blatant departure from the assumption.
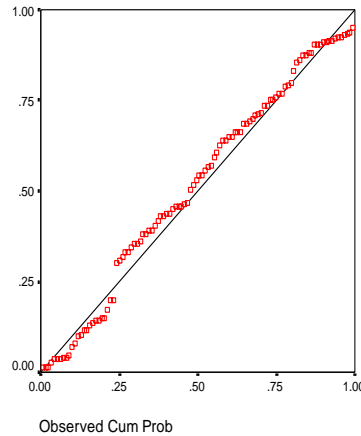

Figure 1: Normal Probability Plot Using Jack-knife for EAS and CA.

The models for the DTMS (all of the form $DV = \beta_0 + \beta_1(IV) + \varepsilon \Rightarrow \hat{D} = \beta_0 + \beta_1(IV)$) produced were as follows:

$\hat{A} = 1.504 + 0.039E$ for the EAS of the DTMS such that $\hat{r} \approx 0.146$, $SE(\beta_0) \approx 0.608$ and $SE(\beta_1) \approx 0.026$; $\hat{P} = 1.030 + 0.084I$ for the IAS of the DTMS such that $\hat{r} \approx 0.299$, $SE(\beta_0) \approx 0.523$ and $SE(\beta_1) \approx 0.029$; and, $\hat{C} = 1.670 + 0.050R$ for the CR of the DTMS such that $\hat{r} \approx 0.227$, $SE(\beta_0) \approx 0.592$ and $SE(\beta_1) \approx 0.031$.

The models for the SAT-M (modelling if it were used as a predictor of performance in the classes) produced were as follows:

$\hat{A} = 0.241 + 0.004S$ such that $\hat{r} \approx 0.194$, $SE(\beta_0) \approx 1.116$ and $SE(\beta_1) \approx 0.002$;

$\hat{P} = 0.695 + 0.003S$ such that $\hat{r} \approx 0.205$, $SE(\beta_0) \approx 0.695$ and $SE(\beta_1) \approx 0.002$;

and, $\hat{C} = -0.519 + 0.005S$ such that $\hat{r} \approx 0.341$, $SE(\beta_0) \approx 1.303$ and $SE(\beta_1) \approx 0.002$.

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[7] $\mathbb{Z}_3\backslash\{0\} = \{-3, -2, -1, 1, 2, 3\}$.

The respective mean grades earned per category of the EAS, IAS, and CR of the DTMS are reported in table 1 and for the SAT-M the mean grades earned per category are reported in table 2.

	Basic Math Math 090	College Algebra Math 100	Pre-Calculus Math 120	Calculus I Math 161
Failed EAS (E ≤ 24)	$\hat{\mu}$ = 2.3404 $\hat{\sigma}$ =1.387 n = 47	$\hat{\mu}$ = 2.2611 $\hat{\sigma}$ =1.393 n=36	$\hat{\mu}$ = 1.900 $\hat{\sigma}$ =1.159 n=17	
Passed EAS (25 ≤ E) Failed IAS (I ≤ 20)		$\hat{\mu}$ = 2.4743 $\hat{\sigma}$ =1.129 n=70	$\hat{\mu}$ = 2.4667 $\hat{\sigma}$ =1,168 n=36	$\hat{\mu}$ = 1.9661 $\hat{\sigma}$ =1.397 n=8
Passed EAS (25 ≤ E) Passed IAS (21 ≤ I) Failed CR (R ≤ 20)			$\hat{\mu}$ = 2.8353 $\hat{\sigma}$ =1.039 n=34	$\hat{\mu}$ = 2.7278 $\hat{\sigma}$ =1.037 n=18
Passed EAS, IAS, & CR (25 ≤ E, 21 ≤ I, ∧ 21 ≤ R)				$\hat{\mu}$ = 2.6652 $\hat{\sigma}$ =1.356 n=23

Table 1: 1998 Sample DTMS Mean Grades, Standard Deviation, and Sample Sizes

	Basic Math Math 090	College Algebra Math 100	Pre-Calculus Math 120	Calculus I Math 161
Level 0 S < 410	$\hat{\mu}$ = 1.383 $\hat{\sigma}$ =1.744 n = 6	$\hat{\mu}$ = 2.800 $\hat{\sigma}$ =1.377 n=5	$\hat{\mu}$ = 3.000 $\hat{\sigma}$ =1.4142 n=2	
Level 1 410 ≤ S < 540	$\hat{\mu}$ = 2.511 $\hat{\sigma}$ =1.271 n = 38	$\hat{\mu}$ = 2.2250 $\hat{\sigma}$ =1.229 n=72	$\hat{\mu}$ = 2.2851 $\hat{\sigma}$ =1.220 n=47	$\hat{\mu}$ = 2.1000 $\hat{\sigma}$ =1.442 n=14
Level 2 540 ≤ S < 600	$\hat{\mu}$ = 3.000 $\hat{\sigma}$ *DNE* [8] n = 1	$\hat{\mu}$ = 2.927 $\hat{\sigma}$ =1.073 n=22	$\hat{\mu}$ = 2.6091 $\hat{\sigma}$ =1.338 n=22	$\hat{\mu}$ = 2.1727 $\hat{\sigma}$ =1.119 n=11
		$\hat{\mu}$ = 3.300	$\hat{\mu}$ = 3.0636	$\hat{\mu}$ = 3.0700

[8] DNE denotes does not exist.

Level 3 X ≥ 600		$\hat{\sigma}$ *DNE* *n = 1*	$\hat{\sigma}$ *=0.825* *n=11*	$\hat{\sigma}$ *=1.389* *n=20*

Table 2: 1998 Sample SAT-M Mean Grades, Standard Deviation, and Sample Sizes

There was not a significant difference in the means for grade earned in any class by any test except for grade earned in Calculus I with respect to the SAT-M, ($t \approx -2.112$; $df = 29$; $p < 0.05$) and none of the predictive validity coefficients were significant.

DISCUSSION

Students having the prerequisite minimum competency skills in mathematics as measured by the EAS, IAS, and CR of the DTMS did not have a significantly higher average level of performance in the respective courses (College Algebra, Pre-calculus, and Calculus I) than did the students who did not have the prerequisite minimum competency skills in mathematics as measured by the EAS, IAS, or CR of the DTMS and were successfully remediated. This lack of significant difference between the grades earned conflicts with the findings of McLoughlin (2000). Note that in the 2000 study, all of the grades earned in the respective courses (College Algebra, Pre-calculus, and Calculus I) were statistically and practically different (see table 3).

	Basic Math Math 090	College Algebra Math 100	Pre-Calculus Math 120	Calculus I Math 161
Failed EAS	$\hat{\mu}$ = 1.877 $\hat{\sigma}$ *=1.357* *n = 178*	$\hat{\mu}$ = 1.231 $\hat{\sigma}$ *=1.159* *n=139*	$\hat{\mu}$ = 1.290 $\hat{\sigma}$ *=1.198* *n=69*	$\hat{\mu}$ = 1.618 $\hat{\sigma}$ *=1.398* *n=11*
Passed EAS Failed IAS		$\hat{\mu}$ = 2.008 $\hat{\sigma}$ *=1.268* *n=214*	$\hat{\mu}$ = 1.952 $\hat{\sigma}$ *=1.255* *n=150*	$\hat{\mu}$ = 1.561 $\hat{\sigma}$ *=1.128* *n=54*
Passed IAS Failed CR		$\hat{\mu}$ = 2.731 $\hat{\sigma}$ *=1.230* *n=29*	$\hat{\mu}$ = 2.462 $\hat{\sigma}$ *=1.198* *n=116*	$\hat{\mu}$ = 2.024 $\hat{\sigma}$ *=1.313* *n=67*
Passed EAS, IAS, & CR				$\hat{\mu}$ = 2.986 $\hat{\sigma}$ *=1.167* *n=50*

Table 3:DTMS Mean Grades 1994 Census (2 significant digit accuracy),

There are several possible explanations for this difference in findings. First, the 2000 study used all of the data (entering freshmen in the fall of 1994) and hence the finding contained within this study could be due to sampling. Second, there was a practical change in policy at the college between the two studies. The last day to drop a course without penalty was changed in the intervening years so that those subjects in the 2000 study had to withdraw from a course by the week after mid-term of a semestre whilst the subjects in this study had until one week before the end of the semestre to withdraw from a course. This policy change may also explain the difference in the mean grades earned per course between and betwixt the two data sets. It could be that since students who were failing a course had approximately six more weeks to decide to drop a course without penalty versus students in the 2000 study there might have been more students withdrawing than in the previous study. Clearly the mean grades earned are substantially higher in this data set than in the 2000 data set (except for mean grade earned in Basic Mathematics (the remedial course)). Third, the student population entering the college in 1998 may be more mathematically adept than those who entered the college in 1994.

Another interesting finding is that in the College Algebra model and the Calculus I model the correlation between the SAT-M score and the grade earned was higher between A and SAT-M ($\hat{r} \approx 0.194$) and between C and SAT-M ($\hat{r} \approx 0.341$) than between the score earned on the EAS and grade earned in College Algebra ($\hat{r} \approx 0.146$) and between the score earned on the CR and grade earned in Calculus I ($\hat{r} \approx 0.227$); only for the IAS was this not so ($\hat{r} \approx 0.299$ between IAS and P as opposed to $\hat{r} \approx 0.205$ between SAT-M and P). The relatively low correlations between the SAT-M score and grade earned is consistent with Bridgeman (1982) but the predictive validity coefficients seem quite lower than found in the McLoughlin (2000) study where the correlations were for the score earned on the EAS and grade earned in College Algebra ($\hat{r} \approx 0.332$), the score earned on the IAS and grade earned in Pre-calculus ($\hat{r} \approx 0.334$), and between the score earned on the CR and grade earned in Calculus I ($\hat{r} \approx 0.433$) which were moderate and did not seem to conflict with

previous studies (e.g.: Bridgeman 1980, 1981; Suddick & Collins, 1984; Dwinnell, 1985; and Meyer, Woodard, and Suddick, 1994).

Let us return to consider the models for the DTMS as opposed to the SAT-M. Note that the slope of the regression equations is quite small for all the models but for each model of a test of the DTMS the slope is greater than that for the SAT-M:

$\hat{A} = 1.504 + 0.039E$ for the EAS of the DTMS versus $\hat{A} = 0.241 + 0.004S$ for the SAT-M;

$\hat{P} = 1.030 + 0.084I$ for the IAS of the DTMS versus $\hat{P} = 0.695 + 0.003S$ for the SAT-M;

and, $\hat{C} = 1.670 + 0.050R$ for the CR of the DTMS versus $\hat{C} = -0.519 + 0.005S$ for the SAT-M. So, it seems that the DTMS might be a better predictor of grade earned in the respective courses (this cannot be stated with any confidence until the comparative part of the study is finished when the researchers gain access to the 1999 SAT-M data and compleat the study as originally designed).

That the DTMS seems to be a better predictor is not surprising given that it was designed as a placement tool. Further, since the levels of the DTMS correspond with the material contained within the courses at the college that one might gain exemption from, Basic Mathematics, College Algebra, and Pre-calculus, it is logical that there would be some correspondence between the score and grades earned in the courses. However, the predictive validity coefficients were low. Nonetheless, the DTMS does seem better suited than the SAT-M on a content level but surprisingly the SAT-M performed as well in many instances as the DTMS. Nonetheless, the predictive coefficients found for the SAT-M for the courses was lower than Bridgeman & Wendler (1989) but they corrected for range restriction, "after correcting for the considerable range restriction that may occur when within-course scores are analyzed, coefficients were typically only in the mid 0.30s."

Also, there is a stability of scores earned on each of the tests of the DTMS which allow for comparatives from one year to the next (see graph 1 for an example) beside the fact that the test itself remains constant form year-to-year.
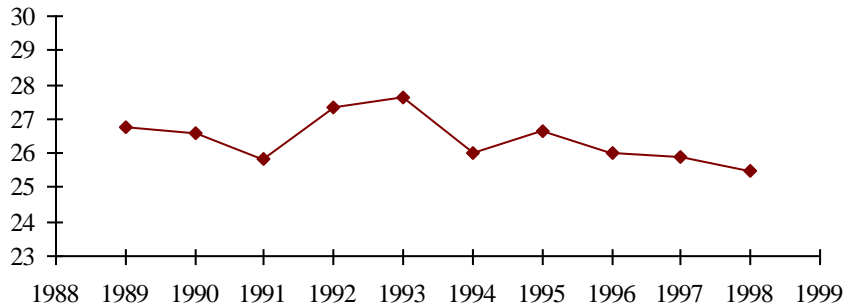
Graph 1: EAS of the DTMS Mean Grades 1989 - 1998.

Indeed, there are more responses required of each examinee (95 questions for the DTMS as opposed to 60 for the SAT-M) so more information is gleaned from the DTMS than SAT-M. Further, there is a correspondence as noted between material in the Basic Mathematics course and the EAS, material in the College Algebra course and the IAS, and material in the Pre-calculus course and the CR; whereas, such correspondence does exist between the SAT-M and the courses but the score earned on the SAT-M may or may not reflect the content per course (there is no way to know since sub-scores are not reported and different examinees can earn equal scores whilst not having the similar content competency). Nonetheless, this might account for the higher correlation between SAT-M and grade earned in Calculus I and seems to support the findings of Bridgeman & Wendler (1989) that the SAT-M seems better suited for use in placement decisions for Calculus I but not for the lower-level courses.

There existed a subtle restriction of range for each of the models for the regressors (score on EAS, IAS, CR, or SAT-M). For example, for the model $\hat{A} = 1.504 + 0.039E$ for the EAS of the DTMS there was a restriction of scores such that it was skewed negatively. Indeed, for high scores on the EAS there were not many grades for College Algebra since those who passed the EAS along with the IAS or CR or both were exempted from the College Algebra course, and therefore placed in either Pre-calculus or Calculus. Similar problems with restriction of range were true for the IAS with grades in Pre-calculus and CR scores and grades in Calculus I. The problem was compounded with the SAT-M scores since that was but one test used in a four-step placement process which though not used in 1998 will be used in 1999. Further, as previously noted there seemed to be a

truncation for the grades earned in the courses which caused a negative skew for the grades in College Algebra, Pre-calculus, and Calculus I.

The truncation affected two of the assumptions necessary for inferences from the regression. It did not affect the assumption of homogeneity of variance; but it did affect the assumption of normality - - there was skewness to the distribution of grades earned in each of the course and with the scores on the tests. However, since regression analysis is robust to mild violations of the normality assumption, the assumption of normality was tenable. The truncation had an effect on the assumption of linearity and on the strength of the relationship between the score earned on the EAS, IAS, CR, or SAT-M and the grade earned in respective course. This truncation had the effect of lowering the estimate of R found in the study. That may explain why such small psychometric indices were found for the EAS, IAS, and the CR in predicting the grade earned in College Algebra, Pre-calculus, and Calculus I (respectively) and for the SAT-M predicting the grade earned in College Algebra, Pre-calculus, and Calculus I. Albeit this result is exploratory and conditional; but, it does make for an interesting comparison with past studies of the DTMS. This is because all of the studies previously conducted differed in that the samples were not truncated as in this study.

For example, Bridgeman (1982) found the correlation between the grade earned in an Elementary Algebra course and the score earned on the EAS for a sample of 73 subjects at a small private 2-year college in the South was 0.46. Further, Bridgeman found the correlation between the grade earned in an Elementary Algebra course and the score earned on the EAS for a sample of 198 subjects at a large public 4-year college in the South was 0.47. For the revised DTMS, Meyer, Woodard, and Suddick (1994) found the correlation between the grade earned in an Elementary Mathematics Concepts and Structures course and the score earned on the EAS for a sample of 60 subjects at a medium sized public 4-year college in the Midwest was 0.49.

It would seem *if* truncation had not been the case in this study, then the resulting psychometric index might be more similar to psychometric indices found in previous studies. However, it may not because the statement is conditional. Further, the SAT-M part

of the study for students entering in 1999 has not been executed so the findings are prefatory at best.

The aforementioned problems seem to indicate that a different method of analysis might or should be employed to determine the comparative utility of the DTMS and SAT-M as placement tools. The researchers have decided to use relative operating characteristic (ROC) analysis in a follow-up study to the present study by re-analysing the data using ROC analysis. There should be less sensitivity to truncation and restriction of range but some of the decision definitions will have to be revised.

Perhaps the most interesting component of the study was not the regression equations, correlations, or any other parametric statistical portion of the study but the effect of the change of policy on the placement schema at the college (which needs to be studied further). Consider the placement that would have been the case had the DTMS not been used and instead the SAT-M had been used to place students in 1998 (see tables 4, 5, and 6). Table 4 shows the placement of the sample that would have been had the SAT-M scores been used for the 186 subjects. Nonetheless, table 5 shows the actual placement for the 186 subject; and, table 6 illustrates a comparison between the two. Note that for the DTMS more students are placed in Basic Mathematics than would have been the case (and might be the case for the 1999 subjects) for the SAT-M. There would have been a less pronounced shift amongst students from the intermediate categories and there is a noteworthy shift also for those placed in Calculus I.

SAT – M			
	Basic Math Math 090	College Algebra Math 100	Pre-calculus Math 120	Calculus I Math 161
Number* (11 non-reported)	9	93	44	28

Table 4: Placement of the sample that would have been had the SAT-M been used in 1998.

DTMS			
	Basic Math Math 090	College Algebra Math 100	Pre-calculus Math 120	Calculus I Math 161

Number	48	71	40	26

Table 5: Actual placement of the sample by the EAS, IAS, and CR of the DTMS in 1998.

		SAT - M				
		Basic Math Math 090	College Algebra Math 100	Pre-Calculus Math 120	Calculus I Math 161	Total
DTMS	Failed EAS (Math 090)	7	38	1	0	46
	Passed EAS Failed IAS (Math 100)	2	41	22	1	68
	Passed IAS Failed CR (Math 120)	0	11	15	12	38
	Passed EAS, IAS, & CR (Math 161)	0	3	6	15	24
	Total	9	93	44	28	174

Table 5: Comparison of the actual placement of the sample by the EAS, IAS, and CR of the DTMS and of the sample that would have been had the SAT-M been used in 1998.

This seems to indicate that there was a shift of students such that less were placed in the remedial class and more into the courses that allowed a student to earn college credit and satisfy core curriculum requirements for mathematics.

According the scoring guide for the SAT-M (2004) of the ETS the score of 410 roughly corresponds with about 15 of 60 questions correct on the SAT-M, the score of 540 roughly corresponds with about 34 of 60 questions correct on the SAT-M, and the score of 600 roughly corresponds with about 42 of 60 questions correct on the SAT-M. The ETS notes that the scores are not predictors of grades in individual classes, the test is not content valid for placement purposes, and is only a predictor of freshman grade point average and should only be considered as one factor amongst a host of factors for admittance to college. The cut scores that are used on the SAT-M used to place students in 1999 to present at the college approximately correspond to 25% correct for the 410 score, $56^2/_3$% for the 540 score, and 70% for the score of 600. Note that the content areas are not delineated in these scores (the approximately 30% of the 60 questions covering Arithmetic (Number and Operations), the approximately 30% of the 60 questions covering Algebra and Functions, the approximately 30% of the 60 questions covering Geometry and Measurement, and the approximately 10% covering Data Analysis, Statistics, and Probability).

Use of the SAT-M scores for a decision of placement into Calculus I does not seem problematic given that the cut scores that are used on the EAS, IAS, and CR are 70% for all of the tests. Nonetheless, the lack of delineation of sub-scores for each of the four content areas covered on the SAT-M *might* lead to a less reliable decision on placement of an entering freshman into mathematics courses. So, it seems intuitively that there is some correspondence in the placement schema between the SAT-M and DTMS for placement into Calculus I. However, for placement into Basic Mathematics, College Algebra, and Pre-calculus there seems to be little if any apparent connection. More research is needed to build evidence as to the advisability of use of the SAT-M scores as a placement tool as opposed to the DTMS.

It should be noted that the use of SAT-M scores is more facile for the administrators, faculty, and students at the college. For placement with the use of the DTMS, the faculty was required to be proctors for the test during the week before classes commenced where

entering freshmen arrived at the campus for new student orientation. The scores were compiled using a scantron machine, but the scores were then manually recorded. No such need exists for the SAT-M since the scores are reported by ETS to the college (at the direction of individual applicants for admission to the college).

The implication of the above result suggests that use of the EAS, IAS, and CR of the DTMS to identify students with deficient skills for college mathematics course work seems viable so that appropriate remediation can be effected for said students; but, the use of the SAT-M seems as suited since both demonstrate poor predictive validity for the data contained herein (if one were to make such a 'dubious' recommendation on the basis of the results contained herein). The practical difference of use of the DTMS scores as opposed to the SAT-M scores seems to be constrained to the number of students placed in the remedial course. There seems to be little evidence of the effect of remediation on a student's performance in College Algebra; but, it should be noted that this was not a primary focus of this study. The inability to finish the study and compare the data results from this part of the study with data from entering freshmen in 1999 is regrettable and frustrating.

Another comment is appropriate at this point of the discussion. Recall the mathematics department's placement was based on the results of a student's performance on three (EAS, IAS, and CR) of the four components of the DTMS through 1998. In 1999, the placement scheme was changed to placement in freshman mathematics courses based on results from the SAT-M. The placement scheme was *supposed* to be placement in freshman mathematics courses was to be based on results from the SATII-Mathematics subject test. The policy was reported to the faculty of the Mathematics Department at the college by the Office of Academic Affairs and Office of Admissions; but, the placement scheme was changed to placement in freshman mathematics courses based on results from the SAT-M and was still the case for entering freshmen in fall of 2003. It is interesting to note that the faculty communicated with the Academic Affairs Office and inquired why the scheme changed; but, received no reply (for four years running).

Nonetheless, policy questions aside, this study investigated the predictive validity of the DTMS as opposed to the predictive validity of the SAT-M in a population composed almost exclusively of African-American males which is interesting in and of itself. The

evidence found in this study somewhat adds to the body of evidence on the predictive power of the EAS, IAS, and CR of the DTMS as a tool in minimum competency testing. The evidence seems neutral (at this stage of the research) as to the use of the EAS, IAS, and CR of the DTMS as a placement tool as opposed to the SAT-M. Clearly more research is needed into the use of the DTMS and the SAT-M as placement tools (for this and other populations). As with any study, there are evidently more questions raised by the research than questions answered by the results.

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