ASHESI UNIVERSITY

EXPLORING THE USE OF COMPUTER-BASED PLACEMENT SYSTEMS IN INCREASING COURSE SUCCESS IN MATHEMATICS TRACKS IN ASHESI UNIVERSITY

UNDERGRADUATE THESIS

B.Sc. Management Information Systems

Christopher Zanu

2019

ASHESI UNIVERSITY

EXPLORING THE USE OF COMPUTER-BASED PLACEMENT SYSTEMS IN INCREASING COURSE SUCCESS IN MATHEMATICS TRACKS IN ASHESI UNIVERSITY

UNDERGRADUATE THESIS

Thesis submitted to the Department of Computer Science, Ashesi University

in partial fulfilment of the requirements for the award of Bachelor of

Science degree in Management Information Systems.

Christopher Zanu

2019

DECLARATION

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:

……..

Candidate's Name:

……...

Date:

……...

I hereby declare that preparation and presentation of the dissertation were supervised in accordance with the guidelines on supervision of thesis laid down by Ashesi University.

Supervisor's Signature:

……..

Supervisor's Name:

……...

Date:

……...

Acknowledgements

I would like to first thank God for seeing me through this period. Indeed, it is not by might nor by power but only by the Spirit of God.

I would also like to thank my supervisor Stephane Nwolley whose help I could not have done without for this piece of academic work to have been produced. Mr. Joseph Mensah was also very helpful and always advised me on what to do even though he was not my supervisor.

I am grateful to my parents for always supporting and encouraging me throughout the process.

I would finally like to thank all my friends who aided me in the carrying out of this project. A special thanks goes to David Sasu who was always ready to brainstorm with me on the way forward in my project. Josephine Abbey was also very instrumental in the carrying out of my experiment as she suggested to me various ways I could sample participants to carry out this study.

Abstract

This study primarily explored the use of computer based placement systems in Africa and as such in Ashesi University more specifically and whether it would ensure course success as compared to using just incoming mathematics grades of college entrants. To do this, a course placement structure was developed which considered both the incoming mathematics grades as well as placement test scores of students. The computer based placement test utilized was ACCUPLACER's Web Application.

Table of Content

Chapter 1: Introduction

1.1 Introduction

In Ashesi University, all students are enrolled unto a Mathematics track in their first year based on their entry examination grades from their senior high schools. Students are enrolled unto one of three tracks: the Calculus track, the Pre-Calculus track or College Algebra track. A survey was carried out to ascertain what factors influenced students' performance in a mathematics tracks and on what basis they should be placed in a mathematics track. While the teaching style of the lecturers was seen to be the greatest factor affecting student performance, 43% of the respondents stated that entry exam grades are not a substantial basis to place students in a mathematics track. 41% of the respondents also expressed preference to take a computerized assessment test to determine their placement in a mathematics track.

This project therefore seeks to assess the course success of using a computer-based placement test to enroll students in mathematics tracks based on their entry examination grades and their placement grades. This will be done by using a web application of one of the most popular computer-adaptive placement test software called ACCUPLACER Web Application in conjunction with a custom web platform to state the course a student is placed in. [13] The output of this project is beneficial to the teachers of the mathematics courses as well as all first-year students.

First year students are used to test the accuracy and validity of the results of the placement system. This is primarily because they are the most recent high school graduates in the school and the most recent students to be enrolled into a freshman mathematics course using their entry examination grades.

1.2 Background

Ashesi University is a liberal arts university in Ghana with the vision of raising ethical and entrepreneurial leaders in Africa. Due to its liberal arts status, the core curriculum of the school consists of courses in social sciences, humanities, mathematics and introductory business and computer sciences courses. [3] This helps builds all rounded students with general knowledge cutting across various disciplines.

All newly admitted students are placed into a mathematics track based on their entrance exams' mathematics scores. The Mathematics courses involves one of three tracks: Calculus track, Pre-Calculus track and the College Algebra track. [3] The school has a placement structure for students based on their incoming (entry examination) mathematics score. Students who are placed in the Calculus track must have taken an Elective or Advanced Mathematics subject in their Senior High School and must have gotten an above average grade. A majority of the rest of the students are placed in Pre-Calculus track while a minority are placed in the College Algebra based on their performance. Students have the option to change their mathematics track placements after discussions with a mathematics faculty by the end of the second week of freshmen classes. If students want to move to a higher level, it would normally require them writing a paper-based placement test administered by a mathematics faculty while moving to a lower level would not require a test.

College Algebra track consists of College Algebra, Pre-Calculus 1, Pre-Calculus 2 and Applied Calculus courses. [3] The College Algebra track helps students develop a good knowledge of basic mathematical principles.

Pre-Calculus track consists of Pre-Calculus and Problem Solving 1, Pre-Calculus and Problem Solving 2 and Applied Calculus courses. The Pre-Calculus track equips students with

an understanding in algebra, functions and inculcates in students heuristic problem-solving abilities for tackling everyday problems. [3] The course uses the study of functions to serve as a basis for understanding calculus. Students take Pre-Calculus 1, Pre-Calculus 2 and Applied Calculus in the fall, spring and summer semesters respectively to complete the mathematics track.

Calculus track consists of Calculus 1 and Calculus 2 courses. According to the University's website, Calculus 1 course provides students a conceptual understanding of variable rates of change, limits and derivatives; mastery of the various techniques of differential calculus; the ability to apply calculus concepts and techniques to real world problems in business, economics and engineering. [3] Calculus 2 course provides students an understanding of the concepts of indefinite and definite integrals; the ability to know when and how to apply the various techniques of integration; and be able to apply the concepts and techniques learned to real world problems in business, economics and engineering.[3]

The course structure of the three courses are similar. Although initially 3 hours, each course has a minimum of 4.5 hours lecture time now and 1.5 hours discussion/laboratory time weekly. The increase of the number of lecture hours was an action undertaken to improve the performance of students in these math courses. During lecture hours more emphasis is placed on concepts rather than rigorous computations. The lab/discussion times are mostly used to solve practice questions with the faculty intern. Students also have access to student math tutors who aid them in understanding concepts taught in class as well as helping them solve math problems.

1.3 Problem Statement

Despite the course structure and additional structures put in place, 10% of students failed their introductory mathematics courses in their first year from a recent survey of first year students. 40% of students got below a C in the course which is below average. In addition to Since these introductory mathematics courses are pre-requisites to subsequent mathematics courses as well as other required courses - such as Microeconomics and Statistics, students who fail these courses now fall behind in terms of their academic progress. This puts an unplanned financial burden on students and parents since students would now have to pay summer school tuition fees to retake these courses during the summer in order to get back on track. This in some cases also shifts the graduation date of students. This causes emotional and psychological stress on some students which can have an adverse effect on students' performance in other courses.

In the same survey, 48.8% students opted for the use of a computer-based placement test for all students to assess students' readiness instead of using just entry examination grades because of a number of reasons:

- Not a reflection of student's actual ability due to passage of time, cheating or illness
- Flawed exams – the WASSCE system
- Assess strengths and weaknesses of students
- Exposure to course concepts

The others who did not opt for the system had the following reasons:

- Sufficiency of entry examination grades to place students
- More pressure and stress on students

- Unpreparedness of students due to passage of time

With all these happening, although the majority opted not to have the system, it is still worthy to research into the ability of computer-based placement systems to enroll students in mathematics tracks based on the readiness of students for those courses and not only their entry examination grades in the case of Ashesi University. This research project focuses on a technological approach to helping teachers and students know which mathematics tracks students are best ready for in order to avoid below average performance and failure as well as the effects of failing a course.

1.4 Research Question and Hypothesis

The research question for this project is:

Do the results of mathematical computerized placement systems ensure increased course success in freshman year mathematics courses?

The hypothesis for the study is:

Mathematical computer-based placement systems increase course success in math courses than the use of incoming grades only.

1.5 Objectives of this project

This project seeks to provide a technological approach of informing lecturers and students of students' readiness to take mathematics courses in their freshman year. In attaining this, the following objectives will be addressed:

1. To identify and implement a computer-based structure for placing students in maths courses by combining incoming grades and placement test grades

2. To investigate whether or not computer-based placement systems improve course success in freshman mathematics courses

1.6 Scope of Project

This research is focused just in Ashesi University. However, outcomes of this project can be applied to other tertiary institutions with regards to teaching tertiary level mathematics to first year students.

1.7 Motivation

The researcher was primarily motivated by an experience of his younger sister who had failed Calculus 1 and had incurred the effects of failing the course. The researcher undertook this project so that it would go on to help a lot of first year students identify their readiness for freshman year mathematics courses.

Chapter 2: Literature Review

2.1 Introduction to chapter

This section reviews academic articles on the history and technology behind computer-based placement exams in colleges as well as its successes and dilemmas through the measurement and concept of predictive validity and course success. This section would also review related works of implementation and usage of computer-based placement exams in Africa.

The researcher will make key relations between the articles and the project.

2.2 Placement Exams

Placement exams are criterion-referenced assessments typically used by colleges as a basis of enrolling entry-level college students into various core courses such as English and Mathematics based on students' current ability. [4] The main objectives of a college placement test include identifying the strength and weaknesses of students and determining students' readiness for college-level work. The two placement tests widely used in the United States are CollegeBoard's ACCUPLACER program and ACT's COMPASS [13]. These programs are both online, computer-adaptive tests with multiple choice questions.

2.2.1 History of Placement Exams

Placement exams date as far back as 17th century when the Massachusetts Law of 1647 pushed forward the setting up of grammar schools with the aim of preparing the youth for universities. [8] During the course of time, placement exams went hand in hand with the practice of remedial courses in order to prepare students who failed to pass placement exams.

Universities in the earlier 19th century started putting in place mandatory remedial and expository programs in writing.

By the 20th century, placement exams, also known as entrance exams, were used by many community colleges in the United States as a means of improving student outcomes. Legislation was passed in California that made placement testing mandatory. These placement exams were now an attempt to cater for students with diverse experiences as well as educational and socioeconomic backgrounds. Legal challenges arose due to the use of placement testing to group students according to ability. The State Chancellor's Office of California had to take action by requiring colleges to report and show proof that the placement programs actually ensure a higher probability of student success in a course.

Despite these challenges, there came the operationalization of computer-based testing in 1985 with College Board's ACCUPLACER testing program being one of the first to be used large scale. [10] ACCUPLACER's testing system had four tests namely, Arithmetic, Elementary Algebra, Reading Comprehension and Sentence Skills. These were primarily used to place entry-level college students in required English and Mathematics courses based on their skillset. Other computer-based tests which sprung up after ACCUPLACER included Certified Network Engineering (CNE) examination, Graduate Record Examination (GRE), Graduate Management Admission Test, Architect Registration Exam amongst others. [10] These examinations till date are still computer based.

2.2.2 Technology behind placement exams

The underlying common factor among most of these computer-based testing systems is that they employed computerized adaptative testing. [10] Other methods employed include the

fixed test form and computer adaptive multistage testing.[10] This paper will, however, focus on computerized adaptive testing.

Computerized adaptive testing (CAT) involves tailoring the difficulty of test items of an examination to the apparent ability of each student. The CAT is therefore item responsive such that after every answer given by the examinee, it adjusts the difficulty level of the next question to better suit the proficiency level of the examinee. The primary goal of CAT is that it maximizes the test reliability of the score, that is, a score's genuinely reflection of student's ability while reducing measurement error.[10] This is to ensure that exams are neither too easy nor too difficult for examinees and as such serves as a diagnostic tool to determine the apparent proficiency level of an examinee.

CAT is built on the principle of item response theory (IRT) as propagated by Lord. IRT is focused on two assumptions: a) the performance of an examinee on a test item can be predicted by a set of factors called traits or abilities and b) the relationship between examinee's item performance and the set of abilities underlying item performance can be represented as a function or curve. [10]. CATs are thus developed sequentially because of the assumptions of IRT which focus on individual test items performance and not the result from the entire test.

Since the performance of an examinee item is dependent on some proficiency and ability of the examinee, the CAT ascertains an initial proficiency by administering a test item that is of moderate difficulty.[10] If the examinee answers the question correctly, a test item of increased difficulty is then administered to the examinee. If the examinee answers the question wrongly, a test item of decreased difficulty is presented to the examinee. This iterative and adaptive approach continues to the end of the exam and thus is able to determine an overall

proficiency and ability level of a student. This process is demonstrated in the image below where ACCUPLACER CAT adapts based on each response of an individual.

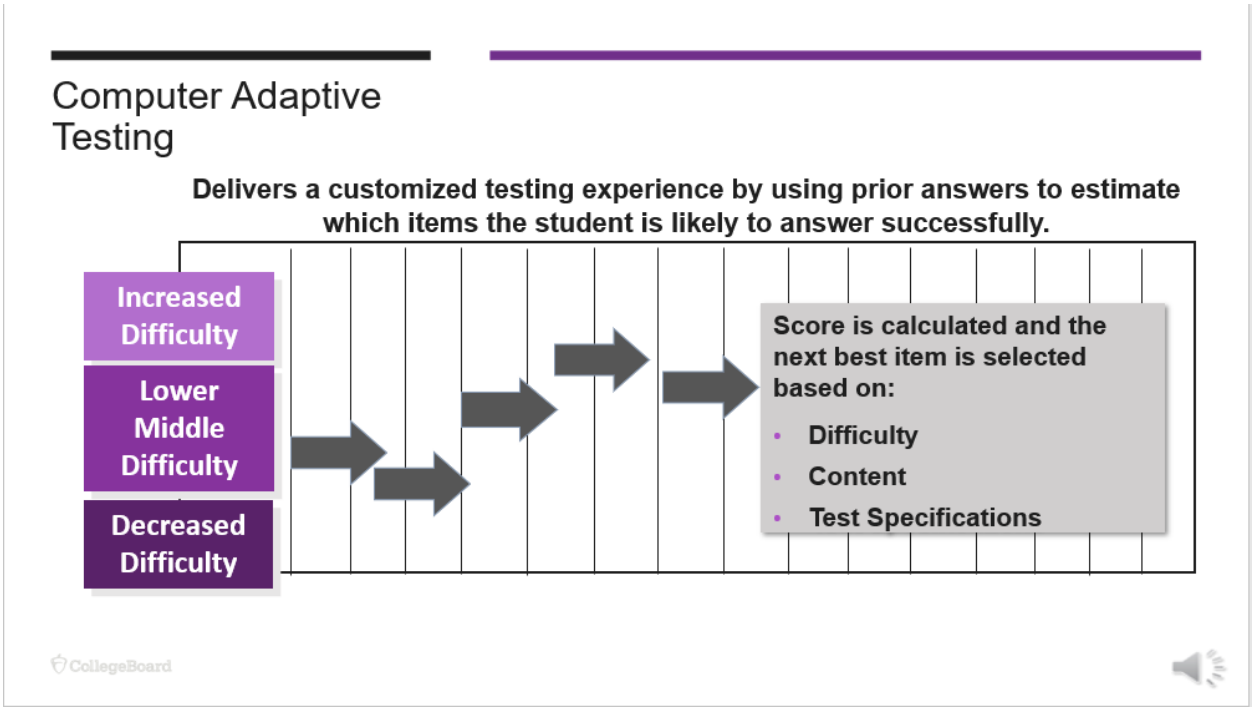


Figure 2.1 ACCUPLACER computer adaptive testing

Due to the goal of Computer Adaptive Tests of detecting and maximizing the score reliability of an exam, it does not focus on the number of exam questions but rather the measure of proficiency of the examinee. [9, 10] CATs thus have several methods for ending a test and organizations are at liberty to select any of available methods based on the purpose of the exam in their organization's context. In some cases, fixed-length tests are administered to all examinees and in other variable-length tests are administered to examinees.[10] Variable length tests are not of relevance to this paper because the CAT used in this paper uses fixed-length tests.

2.2.3 Critique of Computer Adaptive Tests as Placement Exams

CATs, when considered in full context, are more efficient because of the adaptive nature of the exams which is tailored to match examinee's apparent ability. Research also shows that CATs tend to reduce anxiety for examinees because they do not encounter questions which are too difficult for them. [5]

Despite these advantages, the use of placement exams in the form of computer-based testing has however been critiqued by many. The primary argument has been that the use of placement test scores solely is inadequate and insufficient to determine the placement of students in college courses. [4] This stance has been supported by a number of researchers by the measurement of the predictive validity of tests. [13, 14] Correlation coefficient between placement results and final course grade shows a weak positive relationship. [2] This has however proven to be countered with the inclusion of companion measures such as demographic variables, student dispositional data and situational variables. [2,6] The research especially showed that the student dispositional variables such as high school GPA, past academic performance and previous courses studied had a stronger effect on student's likelihood to succeed in a course. [2].

2.3 Predictive Validity and Course success

The concept of predictive validity is one which is very much linked to the concept of placement testing. [11] Predictive validity is the extent to which a score on a scale or tests predicts scores on some criterion measure. There have been a lot of studies on the predictive validity of placement exams to determine student success in college courses. [11]

Packman and Mattern in their research analyzed the predictive validity of the use of ACCUPLACER placement exams to place students in a course that they are likely to succeed in. [11] Their study meta-analyzed a sample of 17 placement studies to estimate the actual validity of placement decisions made in these schools. Packman and Mattern employed the use of a definition of success in a course being a "C or higher" or a "B or higher".[10]

This definition of success as used by Packman and Mattern was adopted in this study.

2.4 Multiple factors in College Placement Decisions

The National Council on Measurement in Education (1995) in its *Code of Professional Responsibilities in Measurement* stated that:

> Persons who interpret, use and communicate assessment results have a professional responsibility to use multiple sources and types of relevant information about persons or programs whenever possible in making educational decisions.[12]

There are other standards in the United States which also assert that decisions which will have an impact on a student should not just be based solely on scores from a single test but also other relevant information. [1, 12] Institutions which provide the platforms for CATs to colleges such as College Board have taken into consideration these standards and measurements and aligned the functionality and guidelines of their CATs systems as such.

College Board developed a taxonomy on multiple factors that should be considered when using its ACCUPLACER scores to make placement decisions for students.[6] The factors are classified into cognitive and non-cognitive factors where cognitive factors represent academic measures such as GPA and placement test scores and non-cognitive factors stand for non-academic measures such as attitudes towards homework. The image below describes this taxonomy.[6]

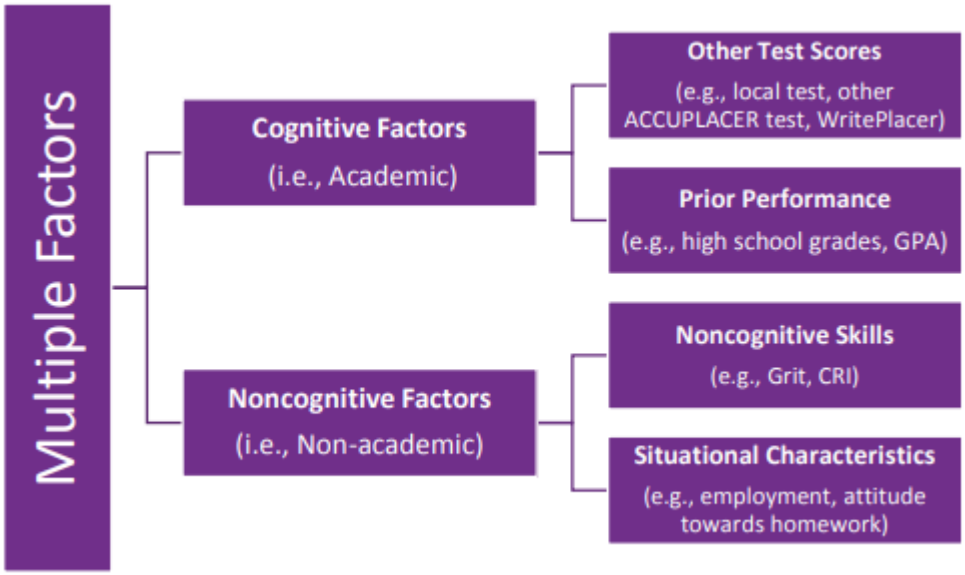


Figure 2.2 Taxonomy of Multiple Factors Used in Making Placement Decisions Using ACCUPLACER Tests

College Board further developed two approaches for making placement decisions, namely the additive approach and the decision tree approach. [6] The additive approach deals with the use of cognitive, academic factors such as GPA and placement test scores to make decisions. Various academic measures are weighted and summed up to get the placement score in the form of

$$S = a_1S_1 + a_2S_2 + a_3S_3 \ldots + a_nS_n + b$$

where S = placement score

S_i = score on measure i

a_i and b are scalars

for $i = 1, 2, 3, \ldots, n$.

The decision tree approach involves displaying the decision-making process of placing students with various circumstances that could occur and their possible outcomes. This

approach combines both cognitive and non-cognitive factors to make placement decisions for students.[6] It is mostly used when students do not attain the pass score for the placement exams and so in order not to go against standards set, other relevant factors are considered to place the student.

This paper adopted on the decision tree process but only for cognitive factors.

2. 5 Mathematical Placement Tests

Most colleges in the United States require all admitted undergraduate students to take some form of mathematics in their first year. [4] Some of these mathematics courses include PreCalculus, Calculus I, Calculus II, Pre-College Algebra and College Algebra amongst others. Mathematical placement tests are thus taken to diagnose students' strengths and determine which mathematics courses students would take in their first year. Admission tests are not used solely for placement because of the way different colleges have varying course structure, requirements and content of their mathematics courses.

The most popular mathematical placement tests used in the United States include is ACCUPLACER. [14] ACCUPLACER is an integrated system of computer-adaptive assessments designed to evaluate students' skills in reading, writing, and mathematics. This paper will focus more on the mathematics evaluation component of ACCUPLACER.

2.6 Mathematical Placement Tests in Africa

Very few colleges and universities in Africa offer placement tests for their students. This is primarily due to difference in curriculum structure and content of both systems. Most universities and colleges require all their students a level of mathematics in their first year regardless of their major. As such there are different levels of mathematics to cater for different

proficiency levels of all students. However in Africa, most universities and colleges only require students in relation to their major. This means that if one's major does not require mathematics, one is most likely not to take a mathematics course. As such there are no remedial or mathematics courses as students are expected to have the required level of proficiency by virtue of the fact that they have been enrolled into that major.

United States International University-Africa is one of the schools in Africa that uses placement exams to determine students' level of skills and knowledge in reading, writing, math and ICT. This is done for students in their orientation week and is computer based as well.[15]

In Ashesi University however, placement exams are not taken by all first-year students although all first-year students are required to take a mathematics course in their first year. The students are placed in their courses by their entry exams mathematics grade. Students who are uncertain of their placement request to take a paper-based placement test to determine their readiness for a course.

2.4 Contribution of Thesis

This thesis seeks to assess the course success of computer based mathematical placements can have in a tertiary university in Africa

Chapter 3: Methodology

3.1 Introduction to Chapter

This study seeks to analyze whether the results of computer based mathematical placement tests are valid in placing students in freshman mathematics course in Ashesi University. This chapter describes the processes the researcher adopted to develop a placement structure which combined both incoming grades and placement test grades. It also describes the ACCUPLACER Web App as the placement test tool going to be used administer placement tests to students. Both a quantitative and a qualitative approach were used to answer the research question. It also outlines the data collection and data analysis tools.

3.2 Research Approach

3.2.1 The Placement Test

This study employs Collegeboard's ACCUPLACER Web App as a placement test. ACCUPLACER is a placement program developed by Collegeboard which is used in colleges in the United States to place students in courses based on a diagnostic test as well as other factors to assess their readiness for a course and place them accordingly. [11,14] ACCUPLACER has developed a variety of placement tests over the years which include Ivy League School tests, Classic ACCUPLACER tests and Next Generation ACCUPLACER tests. This study employs the Next Generation Accuplacer test.

Next Generation Accuplacer tests readiness for Math and English courses in colleges and consists of the following tests[7]:

- Reading
- Writing

- Arithmetic
- Quantitative Reasoning, Algebra and Statistics(QAS)
- Advanced Algebra and Functions(AAF)

The Reading and Writing tests are the English tests while the Arithmetic, QAS and AAF are the mathematics tests. This study employs the QAS and AAF tests because of the level of mathematics offered in Ashesi University.

QAS is a mathematical computer adaptive test that covers the following topics: rational numbers; ratio and proportional relationships; exponents; algebraic expressions; linear equations; linear applications; probability and sets; descriptive statistics and geometry concepts. [7]

AAF is also a mathematical computer adaptive test that covers the following topics: linear equations; linear applications; factoring; quadratics; functions; radical and rational equations; polynomial equations; exponential and logarithmic equations; geometry concepts and trigonometry. [7]

Both QAS and AAF are multiple choice tests which are computer adaptive. [7] This means that after a student answers a question, a student cannot go back to answer the question because it interferes with the adaptive nature of test. The tests are also not timed

3.2.2 Development of Placement Structure

The first thing that was done was to develop a placement structure that was not only based on incoming grades but then also included an additional variable of placement test grades. To do this, the current placement structure being used in Ashesi University was reviewed. (Appendix 1)

The researcher first decided to consider only the WASSCE and the IGCSE examinations for this research. This is because based on preliminary studies, the researcher observed that majority of students who were admitted applied with either of these two examinations results.

The researcher then also observed the course placements of students in the original placement structure. Based on those course placements, the researcher selected placement tests appropriate to those original course placements. Students who were supposed to be placed originally in Calculus were required to take the Advanced Alegbra and Functions test. Students who were to be originally placed in Pre-Calculus and College Algebra were required to take the Quantitative Reasoning, Algebra and Statistics test. These decisions and choices were made based on surveying several schools' placement structures which employed the use of ACCUPLACER tests to enroll students in different levels of Mathematics courses. The Advanced Algebra and Functions test was typically used to test students who were pursuing a calculus course involving differentiation and integration and their respective applications in real life. The Quantitative Reasoning, Algebra and Statistics test was typically used to test students who were pursuing a mathematics level lower than Calculus.

The researcher then had to set cut off points/pass marks for the various tests. These cut off points were selected based on the incoming grades of students. Students who performed well (an A or B) in their incoming examinations had lower cut off points while students who below average (below C) had higher cut off points. All candidates were not given the same cut off point in order not to discredit their previous performance in their incoming examinations. Students who passed the cut off point for the placement test were placed as seen in the table below:

Entry Examination Grade	Placement test	Pass Mark	PASS	FAIL
WASSCE Core Math Only with C4, C5 or C6	QAS	70%,	Pre-Calculus	College Algebra
WASSCE Core Math Only with B or A	QAS	55%	Pre-Calculus	College Algebra
WASSCE Elective Math with C or below	AAF	70%	Calculus	Pre-Calculus
WASSCE Elective Math with B or A	AAF	65%	Calculus	Pre-Calculus
A-Level Math D or below	AAF	80%	Calculus	Pre-Calculus
A-Level Math C or higher	AAF	55%	Calculus	Pre-Calculus
O-Level/IGCSE only with C or below	QAS	80%	Pre-Calculus	College Algebra
O-Level/IGCSE only with A or B	QAS	55%	Pre-Calculus	College Algebra

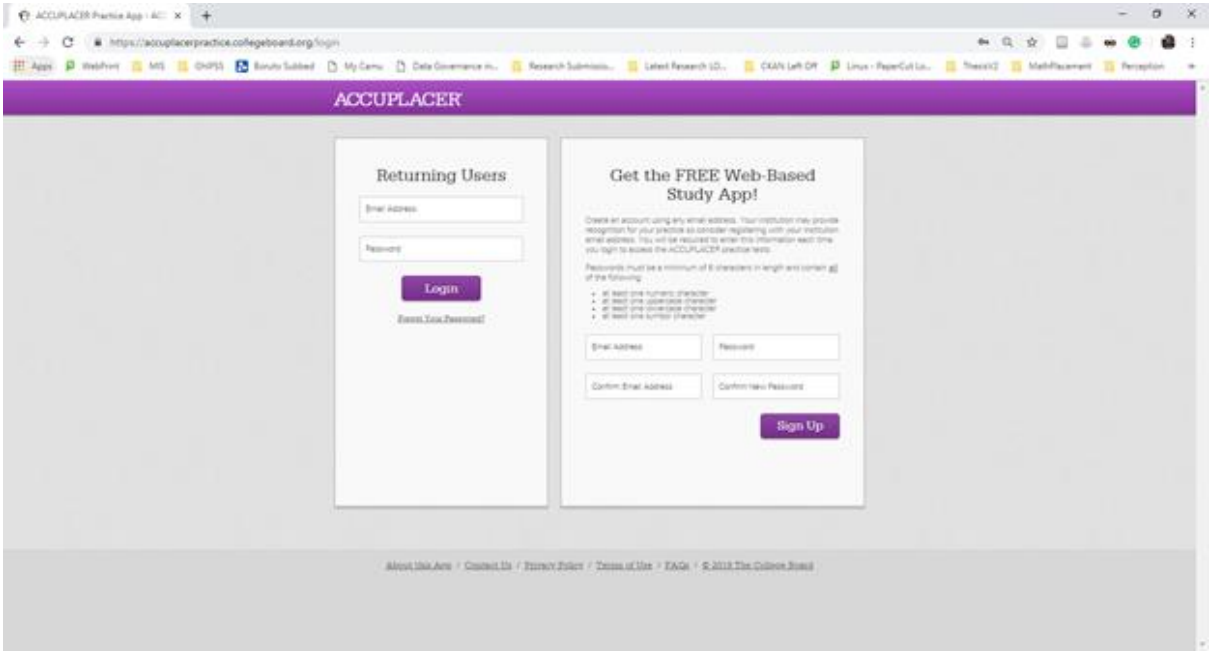
3.2.3 Web Platform

After developing the placement structure, in order to automate the system, the researcher developed a simple website which students could use to do four things:

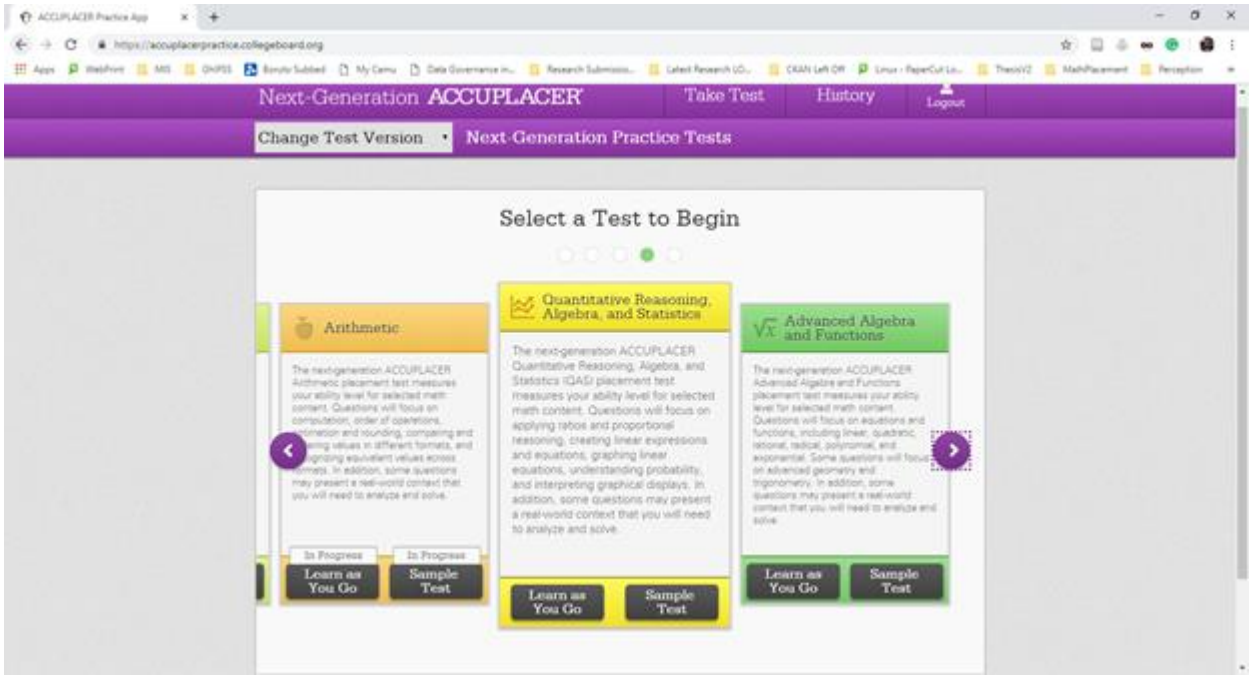
- Identify which test the student is to take
- Redirect the student to the ACCUPLACER web app
- Input score and receive placement from the program
- Give feedback on the entire system

Students would use the system as follows:

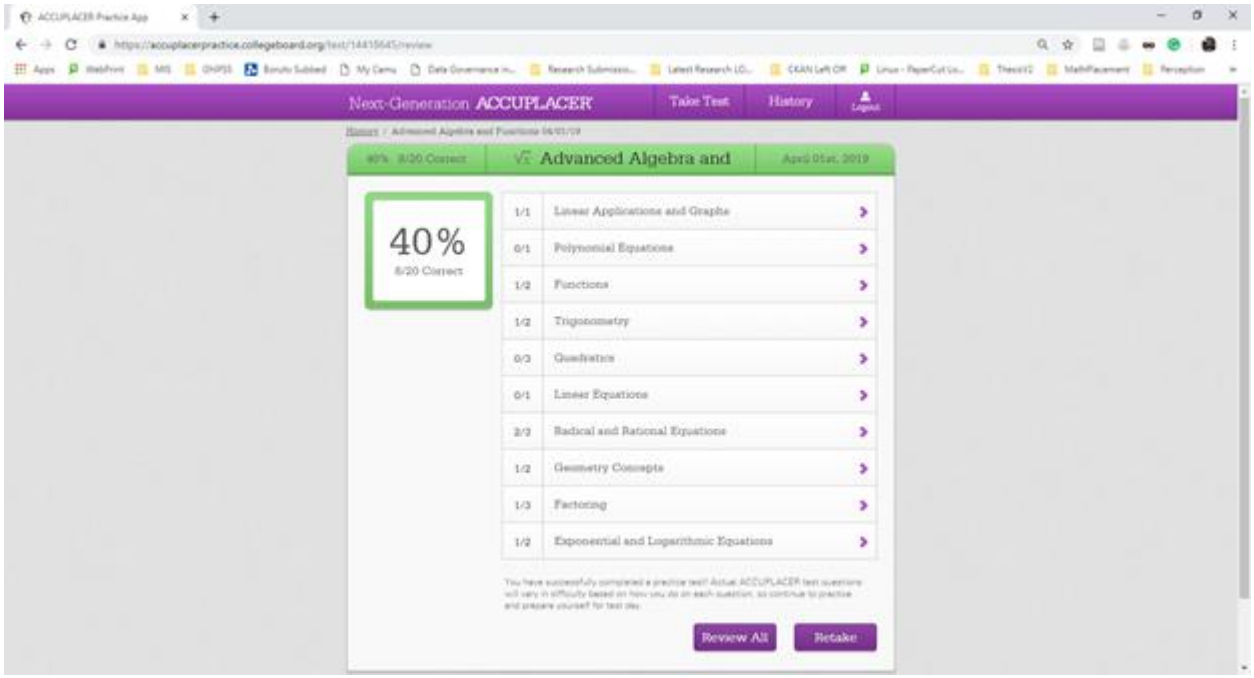
1. Students select their incoming grade and then the placement website displays which test they are supposed to take.
2. Students are then redirected to the ACCUPLACER website.
3. Students were required to sign up unto ACCUPLACER using an email address and a password of their choice.



4. Students then change the version to Next Generation Placement Test.
5. Students choose to take either the QAS or AAF test based on what was communicated to them by the website.



6. Students receive score after taking the placement test and are allowed to review the correct solutions for the entire test.



7. Students then return to the placement website and input their placement test scores.

8. The placement website displays their course placement.
9. For purposes of the research, students are also asked to fill a feedback form which was embedded in placement website.

3.3 Experimentation Design

In order to answer the research question, the study was designed with freshmen as the participants in the study. This is because it is college entrants who take placement tests in order for college institutions to enroll them in courses based on their readiness. Students should have been enrolled in either College Algebra, Pre-Calculus 1 or Calculus 1 in the Fall Semester. This is primarily because the research compares the end of semester grades in these courses to the original placement by Ashesi as juxtaposed to the placement by the placement structure developed in this study.

The test was carried out to through an unmoderated usability test. Participants were contacted through email and were conveyed instructions over through that medium. This is because the research was carried out during the weekend and thus availability of students to carry out such a test was limited.

Participants were selected through convenience sampling. 50 participants were contacted. However only 37 participants responded. Out of the 37 who responded, 19 took Calculus, 12 took Pre-Calculus and 6 took College Algebra.

3. 4 Data Collection and Analysis

Quantitative and qualitative data would be obtained from the study. Quantitative data would be the placement scores while qualitative data would be the feedback from the form.

The placement provided by the system would be compared to students' performance in the courses they were placed in to see if the program was accurate in placing students.

Microsoft Excel was the software used to analyze the data collected. It was selected because it has features which make the analysis and presentation of data very easy. The table feature was used to filter the data collected. Functions such as the COUNTIF, IF, AVERAGE and SUM were used in analyzing the data. Charts were also used in the presentation of the data.

3.4.1 Course success calculation

Course success of the original placement structure and computer-based placement structure would be attained by calculating the success in the courses by using the following formulas [11]:

i) Where course success is defined as "obtaining a B or higher":

Course success (percentage) = [(A + B)/(A + B + C + D)] * 100

Where A = number of students who obtained an A or A+ in the course

B = number of students who obtained an B or B+ in the course

C = number of students who obtained an C or C+ in the course

D = number of students who obtained an D, D+ or E in the course

ii) Where course success is defined as "obtaining a C or higher":

Course success (percentage) = [(A + B + C)/(A + B + C + D)] * 100

Where A = number of students who obtained an A or A+ in the course

B = number of students who obtained an B or B+ in the course

C = number of students who obtained an C or C+ in the course

D = number of students who obtained an D, D+ or E in the course

Chapter 4: Results

4.1 Purpose of Chapter

This chapter explains the data gathered from the methodology used to answer the research questions of this study. It would thus show the analysis of data and how it aids determine the validity of the computer placement as compared to just using the original placement structure the school uses.

4.2 Results

4.2.1 Overall Validity of Incoming Mathematics Grades

The final grades at the end of the math courses – Calculus, Pre-Calculus and College Algebra - were as follows:

Table 4.1: Final grades at the end of math courses

Grades	Frequency
A+, A	8
B+, B	17
C+, C	8
D+, D, E	4
TOTAL	**37**

The course success and as such the predictive validity of the students' incoming mathematics grades were as follows:

Table 4.2: Overall measure of course success and validity of original placement structure

Measure of Success	Percentage
B or higher	68%
C or higher	89%

This goes to show that the incoming mathematics grades of students were valid in placing students in these courses since 68% and 89% of students attained success in a course where success was measure as B or higher and C or higher respectively. This course success and validity is very strong when solely incoming mathematics grades are used to place students in courses.

4.2.2 Validity of Both Incoming Mathematics Grades and Computer-Based Placement with Converging Placements

Out of the 37 students, both the school's original placement structure and the computer-based placement system placed 24 students in the same courses. For example, based on just incoming grades which is the original school placement method, student A was placed in the Calculus course. Also after using the computer based placement system, student A was also placed in the Calculus course by the system. Thus, both systems placed the student in the same course.

The grades of the students having the same placements as per their respective courses are as follows:

Table 4.2 Grade breakdown of students with converging placements from both placement systems

Grades/Math Courses	Calculus	College Algebra	Pre-Calculus	Grand Total
A+, A	4		2	6
B+, B	7		5	12
C+, C	2	2		4
D+, D, E	1		1	2
Grand Total	14	2	8	24

The validity of the two systems with respect to their converging and common placements are seen in the table below:

Table 4.3: Measure of course success and validity of both placement systems for converging placements

Measure of Success	Percentage
B or higher	75%
C or higher	92%

The measure of success and as such the validity of the placements are higher when the divergent placements of the two systems are eliminated.

4.2.3 Validity of Both Incoming Mathematics Grades and Computer-Based Placement with Diverging Placements

For the 13 students who were placed in different courses by the two respective structures in comparison, below are their original placements, the grades they got in those courses and the courses the computer placement system placed them in.

Table 4.4 Diverging student placements with final course grades

Original Placement	Grades	Computer Placement System
Calculus	C+, C	Pre-Calculus
College Algebra	A+, A	Pre-Calculus
College Algebra	A+, A	Pre-Calculus
College Algebra	B+, B	Pre-Calculus
Calculus	B+, B	Pre-Calculus
Calculus	C+, C	Pre-Calculus
Calculus	D+, D, E	Pre-Calculus
Calculus	C+, C	Pre-Calculus

Pre-Calculus	D+, D, E	College Algebra
Pre-Calculus	B+, B	College Algebra
Pre-Calculus	B+, B	Calculus
College Algebra	C+, C	Pre-Calculus
Pre-Calculus	B+, B	College Algebra

The summary of the grades attained above are as follows:

Table 4.5 Final grades of students with divergent placements from both placement systems

Grades	Frequency
A+, A	2
B+, B	5
C+, C	4
D+, D, E	2
TOTAL	**13**

Based on the above grades, the validity of the original placement (based on incoming mathematics grades only) in the case of these students with divergent placements is seen in the table below:

Table 4.6 Measure of course success and validity of original placement system for divergent placements

Measure of Success	Validity Percentage
B or higher	54%
C or higher	85%

Further analysis on the data above shows where the computer placement either placed a student in a lower or higher math level course than the original course placement. For example, Student A was placed in Calculus per the default placement structure but the computer placed Student A in Pre-Calculus. Such placement is placement in a "Lower level math course" while the vice versa would be placement in a "Higher level math course". Below is a table with

the frequency of higher and lower level placements of the computer placement as compared to the original placements

Table 4.7 Computer placement compared to original placement

Computer Placement compared to Original Placement	Frequency
Lower level Math Course	8
Higher level Math Course	5

In analyzing instances where the computer placement recommended that students moved to a higher level, students got the following grades:

Table 4.8 Grades of students with recommended higher computer placements

Grade	Frequency
A+, A	2
B+, B	2
C+, C	1
D+, D, E	0
TOTAL	5

In order to get a possible grade in the case that the student had been placed in the higher-level course as the with the computer system, the grade of the student was reduced by one level. For example, supposing Student A was originally placed in the College Algebra course and attained a B+ or B, and the computer placement program placed the student in Pre-Calculus, it is assumed that the student would get a C+ or C on the basis that he or she is in a higher level of mathematics. The following table contains the grades students would have attained had they been placed in a higher level of mathematics as per the computer placement:

Table 4.9 Predicted grades of students placed in higher level by computer system

Grade	Frequency
A+, A	0
B+, B	2
C+, C	2
D+, D, E	1
TOTAL	5

In analyzing instances where the computer placement recommended that students moved to a lower level, students got the following grades:

Table 4.10 Grades of students with recommended lower computer placements

Grade	Frequency
A+, A	0
B+, B	3
C+, C	3
D+, D, E	2
TOTAL	8

In order to predict a grade in the case that the student had been placed in the lower-level course as the with the computer system, the grade of the student was increased by one grade level. For example, supposing Student A was originally placed in the Pre-Calculus course and attained a B+ or B, and the computer placement program placed the student in College Algebra, it is assumed that the student would get an A+ or A on the basis that he or she is in a higher level of mathematics. The following table contains the predicted grades students would have attained had they been placed in a lower level of mathematics as per the computer placement.

Table 4.11 Predicted grades of students placed in lower level by computer system

Grade	Frequency
A+, A	3
B+, B	3
C+, C	2

D+, D, E	0
TOTAL	8

After attaining this information, the overall predicted grades of the Computer Placement System is as follows:

Table 4.12: Predicted grades at the end of math courses by computer placement system

Grades	Frequency
A+, A	9
B+, B	17
C+, C	6
D+, D, E	5
TOTAL	**37**

The course success and as such the predictive validity of the computer placement system grades were as follows:

Table 4.13: Overall measure of course success and validity of computer placement system

Measure of Success	Validity Percentage
B or higher	70%
C or higher	86%

4.3 Feedback from the form

Students were asked to fill a form after using the placement system and the quantitative and qualitative data are outlined below.

4.3.1 Factors that affected performance in the course

Students were asked to rate factors that affected their performance in the course on a scale of 1 to 5, 1 being the lowest and 5 being the highest. The following table presents the average of the responses obtained:

Table 4.14 Factors that affected performance in the course

Grades/Factors	**Difficulty of Concepts**	**Level of math knowledge before the course**	**Learning style**	**Teaching style**
A+, A	3.125	3.625	3.875	3.375
B+, B	3.118	2.882	3.235	3.412
C+, C	2.375	1.375	3.5	3.125
D+, D, E	2.75	4	4	3
Average	2.85	2.98	3.65	3.23

4.3.2 Challenging Relevant Questions and Recommendation

Students were asked if the placement test presented them with relevant and challenging questions relevant to the mathematics course they were placed in. Students were also asked if they would recommend that all first years use the computer-based placement system to be placed in math courses instead of just using incoming mathematics grades. The following table presents the you with the responses obtained:

Table 4.15 Challenging relevant questions and recommendation

	Challenging relevant questions		Recommendation	
	Frequency	Percentage	Frequency	Percentage
YES	18	48.64%	32	86.5%
NO	19	51.36%	5	13.5%

4.3.3 Features of the Placement System

The table below presents features of the placement system that users were asked on a scale of 1 to 5, with 1 being the lowest and 5 being the highest.

Table 4.16 Rating of features of computer placement system

	Easy to use	Navigation	Feedback after taking exam	Design	Overall
Average Score	**4.027777778**	**4.055555556**	**4.027777778**	**3.722222222**	**4.162162162**

4.4 Evaluation of Results

Table 4.17 Summary of Original and Computer Based placement course successes

	Original Placement Structure		Computer based placement structure	
Measure	Success	Failure	Success	Failure
B or higher	68%	32%	70%	30%
C or higher	89%	11%	86%	14%

From the placement results obtained, it was observed that with regards to the course success, the original placement structure had a higher course success when one considers the measure of success to be obtaining a C or higher in the mathematics course. Although the computer-based placement structure had a higher success rate when the measure of success was a student obtaining a B or higher, it had a higher failure rate when the measure of success was a C or higher. This has more of an impact because in Ashesi University, students fail a course when they get a D+, D or E. Therefore, had the computer placement structure been used, more students would have failed their freshman mathematics course as compared to if they had been placed just by their incoming mathematics grades.

The statistical difference however between the course successes of the two systems is relatively insignificant. This indicates that both systems are similar. This can be attributed to the fact that both systems had a majority of convergent placements. Had there be more divergent placements from both systems, the course successes may have been significantly different. This can also be attributed to the fact that the predicted final grades of the computer-based placement were not independent but were dependent on the final grades of the original placement structure.

Also, from the qualitative data gathered from the feedback form, although majority of the students recommended that the computer-based placement system be used and rated it positively, about half of the students who used the system did not find the questions in the placement test challenging. This may have also affected the results of the computer-based placement system.

Thus, despite majority of respondents recommending that the computer placement system should be used in the stead of just incoming mathematics grades, the computer-based placement structure has a lower predictive validity and course success as more students may still fail their courses if such a placement system is used.

The hypothesis that mathematical computer-based placement systems increase course success in math courses than the use of incoming grades only is thus rejected.

Chapter 5: Conclusions and Recommendations

5.1 Application and Practical Significance of Study

This study primarily explored the use of computer-based placement systems in Africa and as such in Ashesi University more specifically and whether it would ensure course success as compared to using just incoming mathematics grades of college entrants. To do this, a course placement structure was developed which considered both the incoming mathematics grades as well as placement test scores of students. The placement test utilized was ACCUPLACER's Web Application.

Based on the tests conducted and data analyzed, the research showed that the computer-based placements did not ensure an increase in course success but rather on the contrary increased in course failure by a margin. As much as this is the result obtained, this study provides African tertiary institutions with a structure like Ashesi University, an alternative computerized framework for placing students in first year mathematics courses.

The results of this study are also useful to school administrators as it points out students' perspectives on the use of their entry examination grades to place them in mathematics courses.

5.2 Limitations of Study

The ideal nature of the study would have required a fully adaptive computer placement test system. Whereas the ACCUPLACER Web App could serve the purposes of this study, it is not as fully adaptive as an actual licenser ACCUPLACER system would have been.

The number of students and sampling method used were not the best. This is because the sample size ended up being insufficient to carry out a truly statistical study and as such participants all had similar traits.

The time in which the study was conducted affected the results. This is because the optimum time to have taken the placement test would have been before students were enrolled in a course and not after they have ended the course. The use of this method led to prediction of grades which may have affected the output of the study.

The researcher could also not develop a website to work in tandem with the ACCUPLACER Web App and as such, communication of placement results to students had to be done manually. This did not allow students to experience a fully, seamless technological process in using the system but had to wait for manual communications from the researcher. This did not depict a full web placement system.

The researcher also did not have the ability to alter or add to the bank of questions which were being administered to students. This was a limitation as the questions students were tested on were not challenging.

5.3 Future Work

Future work the researcher would like to propose is the carrying out of a similar study with the use of a fully adaptive test system as well as the inclusion of non-cognitive factors in the placement decision-making process. This study should be employed at the beginning of a student's journey in the university. Such a study would be devoid of flaws and will either validate or disprove the results of this paper.

This will be the first of its kind in Africa and could go a long way to improve and if possible change the narrative of the mathematics experience of students in Africa as students would be placed in courses that are not only challenging for students but then the likelihood of success is also high.

References

[1] American Educational Research Association. 2014. *Standards for Educational and Psychological Testing, 2014 Edition*. American Educational Research Association

[2] William B. Armstrong. 2000. The Association Among Student Success in Courses, Placement Test Scores, Student Background Data, and Instructor Grading Practices. *Community College Journal of Research and Practice* 24, 8 (September 2000), 681–695. DOI:https://doi.org/10.1080/10668920050140837

[3] Ashesi University. 2016. Courses - Ashesi University. Retrieved April 1, 2019 from https://www.ashesi.edu.gh/academics/programmes/arts-and-sciences/liberal-arts-core-courses.html

[4] Elisabeth A. Barnett and Vikash Reddy. 2017. College Placement Strategies: Evolving Considerations and Practices. (February 2017). Retrieved March 27, 2019 from https://ccrc.tc.columbia.edu/publications/college-placement-strategies-evolving-considerations.html

[5] Betty Bergstrom and Richard C. Gershon. 1991. Individual differences in computer adaptive testing: Anxiety, computer literacy, and satisfaction. Paper presented at the Annual Meeting of the National Council on Measurement in Education, San Francisco, CA.

[6] College Board. 2018. Multiple Factors in College Placement Decisions 2018. Retrieved from https://accuplacer.collegeboard.org/pdf/multiple-factors-college-placement-decisions.pdf

[7] College Board. 2016. Next-Generation ACCUPLACER – The College Board. *ACCUPLACER*. Retrieved April 23, 2019 from https://accuplacer.collegeboard.org/educator/next-generation

[8] Dlonne Danns and Christopher M. Span. 2008. History of Schooling. In *21st Century Education: A Reference Handbook*. SAGE Publications, Inc., Thousand Oaks, I-265-I–273. DOI:https://doi.org/10.4135/9781412964012

[9] Ronald K. Hambleton, H. Jane Rogers and Hariharan Swaminathan. 1991. *Fundamentals of Item Response Theory*. SAGE.

[10] Richard Luecht and Stephen Sireci. 2011. (PDF) A Review of Models for Computer-Based Testing. *ResearchGate*. Retrieved March 27, 2019 from https://www.researchgate.net/publication/265622331_A_Review_of_Models_for_Computer-Based_Testing

[11] Krista Mattern and Sheryl Packman. 2009. Predictive validity of ACCUPLACER® scores for course placement: A meta-analysis. (January 2009).

[12] National Council on Measurement in Education. 1995. Code of Professional Responsibilities in Educational Measurement | Request PDF. *ResearchGate*. Retrieved April 1, 2019 from https://www.researchgate.net/publication/234728301_Code_of_Professional_Responsibilities_in_Educational_Measurement

[13] Frederick Ngo and William W. Kwon. 2015. Using Multiple Measures to Make Math Placement Decisions: Implications for Access and Success in Community Colleges. *Res High Educ* 56, 5 (August 2015), 442–470. DOI:https://doi.org/10.1007/s11162-014-9352-9

[14] Judith Scott-Clayton. 2012. *Do High-Stakes Placement Exams Predict College Success? CCRC Working Paper No. 41*. Community College Research Center. Retrieved March 6, 2019 from https://eric.ed.gov/?id=ED529866

[15] USIU-Africa Website. Orientation. *USIU-Africa Website*. Retrieved March 16, 2019 from https://www.usiu.ac.ke/orientation/

Appendix

Appendix 1

Initial Mathematics Placement Based on Incoming Scores and Experience

- WASSCE Core Math Only with C5 or C6 → College Algebra
- WASSCE Core Math Only with C4 → Pre-Calculus 1 OR Meet with a mathematics faculty to decide placement
- WASSCE Core Math Only with B or A → Pre-Calculus 1
- WASSCE Elective Math with C or below → Pre-Calculus 1
- WASSCE Elective Math with B or A → Calculus 1
- A-Level Math D or below → Pre-Calculus 1
- A-Level Math C or higher → Calculus 1
- A-Level Further Math → Calculus 1
- O-Level/IGCSE only with C or below → College Algebra
- O-Level/IGCSE only with A or B → Pre-Calculus 1
- IB Math Studies (Standard Level) with 4 or below → College Algebra
- IB Math Studies (Standard Level) with 5 or higher → Pre-Calculus 1
- IB Math SL (Standard Level) with 4 or below → Pre-Calculus 1
- IB Math SL (Standard Level) with 5 or higher → Calculus 1
- IB Math HL (Higher Level) 1 or 2 → Pre-Calculus 1
- IB Math HL (Higher Level) 3 or higher → Calculus 1
- American Diploma: Algebra 2 or Geometry with C or below → College Algebra
- American Diploma: Algebra 2 or Geometry with A or B → Pre-Calculus 1
- American Diploma: Pre-Calculus or Trigonometry with C or below → Pre-Calculus 1
- American Diploma: Pre-Calculus or Trigonometry with A or B → Calculus 1
- Other Diplomas: B or above in an intensive course handling functions (including polynomial, exponential, logarithmic, trigonometric, rational and radical functions families), with graphing and applications → Calculus; C or below → Pre-Calculus.