Relevance of Mathematics in Undergraduate Economics and Business Administration (EBA) Education

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ABSTRACT

Undergraduate economics and business administration (EBA) students take many mathematics courses during their studies; and those with poor mathematics background often question the significance of the different mathematics courses that they must pass in order to be awarded their degrees. This paper reviewed pertinent literature and utilized a mixed-methods document analysis design to analyze content of 216 official course syllabuses from 12 Ghanaian universities to determine the relevance of mathematics in 8 undergraduate Economics and 10 undergraduate Business Administration curricula. It also proffered recommendations for improving undergraduate students' academic performance in EBA programmes.

Keywords— Economics, business administration, mathematics, problem solving, critical reasoning.

INTRODUCTION

Mathematics is often considered as "Science of all Sciences and Art of all Arts" (Kumar, 2017 p. 273) because it is a discipline that provides the theorems, tools, and techniques for analyzing and solving numerous real-life problems in the sciences (specifically: physical, biological, and social sciences[1]) and in the arts. It "develops the ability to reason precisely and analytically about formally defined abstract structures" (Devlin, 2003 p39); and fosters critical reasoning, logical thinking, and analytical skills (Jaiswal, 2024) "for data analysis and problem-solving" (Avevor, 2022 p. 30). Mathematical tools, concepts, techniques, and proofs are utilized in many EBA courses and professions; because mathematics has strong links with many EBA courses at undergraduate and graduate levels; and the application of its concepts, tools, theorems, and proofs "permeates different fields" (Sun, 2022 p. 1). For instance, mathematics provides various foundational, analytical and predictive techniques and tools that are frequently used in EBA fields such as economics, finance, accounting, marketing, sales management, procurement, logistics/transportation management, inventory management, operations management, et cetera (Jaiswal, 2024; Voßkamp, et al., 2025; Haeussler, et al., 2022); and "one feels helpless in every area of commerce and business without mathematics" (Jaiswal, 2024 p. 240). Many universities in Ghana have included several mathematics courses in the curricula of their undergraduate and graduate EBA programmes.

Ghanaian universities require students to obtain at least grade C6 in West African Senior School Certificate Examination (WASSCE)'s Core Mathematics in order to gain admission for undergraduate EBA studies. The Core Mathematics curriculum encompasses Algebra, Geometry, Trigonometry, Calculus, Statistics and Probability. Thus, students need to pass Core Mathematics at WASSCE prior to their undergraduate EBA studies.

[1] Physical sciences are concerned with non-living things/materials (e.g. geology, astronomy, chemistry, physics, meteorology, et cetera); while biological sciences are concerned with the cycles, environments, and adaptations of life and/or living organisms (e.g. biology, physiology/medicine, dentistry, microbiology, biochemistry, botany, parasitology, pharmacology, agriculture, et cetera). Similarly, social sciences encompass subjects like economics, geography, law, sociology, psychology, social work, political science, business administration, et cetera; while the field of arts includes modern languages, philosophy, classics, communication studies, et cetera.

During semesters 1-4 of their undergraduate studies, students who are pursuing the Economics programme take some common courses (notably: microeconomics, macroeconomics, introduction to business administration, operations management, and principles of accounting) with those pursuing the Business Administration programme. Also, during semesters 5-8, business administration students have options to specialize in any of the following six areas: Accounting, Human Resources Management, Marketing, Entrepreneurship, Banking and Finance, and Business Administration.

Problem Statement

Students' prior mathematics skills have predictive power on (or correlate positively with) their performance in undergraduate EBA courses (Mallik & Basu, 2009; Lagerlof & Seltzer, 2009). Invariably, those with strong background in mathematics tend to excel in their undergraduate EBA courses; while those with weak background in mathematics struggle and tend to perform abysmally in these courses. Due to lack of (or inadequate) prior mathematics knowledge and skills, many undergraduate EBA students often have serious problems coping with (and sometimes drop some) EBA courses that have concepts requiring strong mathematics skills. (Voßkamp, et. al; 2025). Specifically, students with weak background in mathematics usually have difficulties in understanding, appreciating, and applying concepts in undergraduate EBA courses such as Microeconomics, Macroeconomics, International economics, Business finance, Investment analysis, Financial accounting, Operations management, Business research methods, and Project management. They struggle to analyze and solve problems that require the utilization of mathematical tools, concepts and techniques in their EBA courses; and they often attain poor grades in these and related courses. Oftentimes, their mathematics deficiency tends to adversely affect their performance in EBA and related careers. Through a review of pertinent literature and content analysis of course syllabuses, this paper examined the relevance of mathematics in undergraduate EBA education.

Research Question

The single research question is:

RQ. What is the relevance of pre-tertiary and undergraduate mathematics courses in undergraduate EBA education?

LITERATURE REVIEW

Syllabus Analysis and the Relevance of Mathematics

A course syllabus is a formal contract that provides learning outcomes, content, prerequisites, and assessment (Bers et al., 2011); and it captures institutional intent. Syllabus analysis is a rigorous method that is used for curriculum mapping, alignment auditing, and workload analysis (Jacobs, 2004; Harden, 2001) in higher educational institutions; and it reveals what institutions value. Intuitively, if a course syllabus lists mathematical learning outcomes, requires mathematical prerequisites, and allocates assessment marks to mathematical tasks, then mathematics is relevant to that course, regardless of student opinion. Marshall et al. (2024), in a census of 793 U.S. economics programmes, did not survey students; they coded degree requirements and course descriptions. They found that 63% of degrees formally required calculus for intermediate theory and 54% required econometrics, proving that mathematization is a curricular policy, not an instructor preference. Similarly, Landgärds-Tarvoll (2024) in Europe reviewed syllabus and curriculum documents to show that the school-to-university transition fails because secondary school syllabuses promise general mathematical literacy while university-level mathematics syllabuses assume abstract fluency and independent problem-solving.

Mathematical Intensity and Curriculum Progression

International syllabus studies show two consistent patterns: (1) mathematical intensity increases with level, and (2) mathematics is concentrated in a few anchor courses but assumed in many others. For instance, in Spain, Masana and Cebrián (2026) coded syllabuses across full undergraduate economics and business degrees for over 4,700 students and found that mathematics demand did not disappear after Year 1. They also found that

intermediate microeconomics, macroeconomics, econometrics, and finance syllabuses required rigorous calculus, optimization, and matrix algebra. Similarly, Chen and Hu (2021) in China found the same progression; and concluded that when microeconomics syllabuses explicitly required calculus for utility maximization and cost minimization, students without that prerequisite had a 34% higher failure rate, even when they had passed earlier mathematics courses.

Explicit versus Implicit Mathematical Relevance in Syllabuses

Syllabus analysis tends to distinguish between explicit and implicit mathematical relevance. Explicit relevance occurs when a syllabus states a mathematical learning outcome, lists a mathematical topic, or allocates marks to mathematical problems. Implicit relevance occurs when a syllabus contains no mathematical language, but the content cannot be mastered without mathematics (e.g., a Macroeconomics syllabus on IS-LM models, multiplier effects, or growth models).

Research shows that implicit relevance is common and problematic. For instance, Tan and Lim (2020) found in Malaysia that finance and operations research syllabuses made mathematics explicit, while marketing and human resource syllabuses rarely mentioned quantitative outcomes, creating a discipline-split perception among students that mathematics was irrelevant to those courses. Also, Naidoo and Steyn (2023) found in South Africa that BCom students described mathematics as "necessary but painful" precisely because syllabuses presented it as abstract computation rather than as a tool for interpreting business data. In Morocco, Benali and El Khadiri (2019) found that economics syllabuses were mathematically dense but pedagogically thin — they listed topics but not applications. Similarly, Ezurike and Uduagbami (2022) found that Business Mathematics syllabuses in Nigerian polytechnics emphasized computation over application, and Adeyemi and Ojo (2020) linked this to mathematics anxiety. For Ghana, therefore, the question is not only how much mathematics is in the syllabuses, but how it is framed: as a set of techniques to memorize, or as a language for economic and business reasoning.

Literature Gap in Ghanaian Context

No study in Ghana has systematically mapped mathematics across undergraduate Economics and Business Administration syllabuses. Existing Ghanaian evidence is indirect. Mumuni et al. (2010) and Asiedu-Addo and Yidana (2016) established a strong correlation between mathematics and economics achievement at senior high school level using WASSCE scores, but they did not examine university syllabuses. This study, therefore, provides a syllabus content analysis across 12 Ghanaian universities to identify undergraduate courses in Economics and Business Administration requiring strong mathematical skills, techniques, and tools.

METHODOLOGY

This study adopted a mixed-methods document analysis design, combining quantitative content analysis with qualitative curriculum mapping (Krippendorff, 2019; Bowen, 2009). This research design fits the research question because relevance, for this study, refers to the extent to which mathematics is formally required, present, and assessed in official course syllabuses in Ghanaian universities that are offering undergraduate economics and business administration courses. Thus, document analysis (not examination-score study or survey) can answer it, because the course syllabus is the only document that legally and academically commits a university to teach and assess specific content (Bowen, 2009; Bers et al., 2011).

This study is grounded in pragmatism (Morgan, 2007; Creswell & Creswell, 2018) since the research question is practical and policy-oriented (because Ghana Tertiary Education Council, university academic boards, and heads of department need actionable evidence for curriculum review). Pragmatism permits the integration of numerical coding (to show how much mathematics is relevant) and textual interpretation (to show how mathematical relevance is framed), without being constrained by a purely positivist or purely interpretivist stance. Furthermore, relevance is independent of individual perception; and it is identifiable through systematic, replicable coding of curriculum documents.

12 accredited Ghanaian universities were purposively selected based on public availability of approved course syllabuses for 2025/2026 academic year with explicit listing of course learning outcomes and topics. Similarly, 8 economics courses (comprising 4 core and 4 elective courses) and 10 business administration courses (comprising 4 core and 6 elective courses) were purposively selected for this study.

Mathematical requirements were identified through a systematic content analysis of course descriptions, learning outcomes, and topic lists. A coding framework was developed from the literature on quantitative competencies in economics and business administration education and from reading the syllabuses. It has four dimensions: (i) Foundational numeracy (arithmetic, ratios, percentages); (ii) Algebraic and functional reasoning (functions, linear equations); (iii) Calculus and optimizations (derivatives, integrals, constrained optimization); (iv). Statistical and probabilistic reasoning (descriptive statistics, probability, regression). The framework was duly validated by a panel of 5 experts: 2 curriculum specialists, 2 economists, and 1 mathematics professor.

The study proceeded in the following three phases: (1). Retrieving/collecting official programme handbooks and course syllabuses; (2). Numerically coding (i.e., systematic quantitative content analysis) of each course syllabus using the 4-dimensional framework. (iii). Curriculum mapping (i.e., qualitative curriculum mapping) to thematically analyze the wording of learning outcomes, topic lists, and prerequisite statements in order to distinguish explicit relevance (mathematics stated as an outcome) from implicit relevance (mathematics required but not stated). This research design follows established syllabus analysis studies in economics education (Marshall et al., 2024) and curriculum mapping research (Landgärds-Tarvoll, 2024; Krippendorff, 2019; Bowen, 2009; Harden, 2001), where the syllabus is treated as the authoritative artefact of intended curriculum.

To eliminate subjective bias and ensure coding consistency, two independent coders (the author and a senior academic researcher with expertise in mathematics education) coded all 216 (economics and business administration) course syllabuses separately. Thereafter, Cohen's kappa coefficient was used to calculate inter-rater reliability, and the result was $\kappa = 0.84$. Discrepancies were resolved through discussion (i.e., consensus moderation) to ensure that the reported distribution of mathematical requirements reflects a consensual and defensible reading of the syllabuses.

Major Universities Offering Eba Programmes In Ghana

To adequately answer the research question, this paper reviewed the course descriptions, syllabuses as well as recommended textbooks for undergraduate EBA courses of 12 universities in Ghana. Table 1 shows the EBA programme offerings of the 12 universities analyzed for this paper. It reveals that 1-5 i.e., UPSA, UG, KNUST, UCC, and UDS are the five most dominant universities offering EBA programmes in Ghana.

TABLE 1. MAJOR UNIVERSITIES THAT OFFER EBA PROGRAMMES IN GHANA

Institution	**EBA Programmes**
1. University of Professional Studies, Accra (UPSA)	BSc. Business Administration, MBA. Business Management, BSc/MPhil/PhD. Accounting, BSc/MBA. Accounting and Finance, MBA. Petroleum Accounting & Finance, MPhil/PhD. Finance, MBA. Auditing/Internal Auditing, BSc. Business Economics, BSc. Banking and Finance, MSc. Procurement Management, MSc. Pensions Management, MSc. Insurance Risk Management, MPhil/PhD. Management, BSc/MBA/PhD. Marketing, MA. Digital and Strategic Marketing Management, MBA. Corporate Governance, MBA. Total Quality Management, MBA. Impact Entrepreneurship and Innovation

2. University of Ghana, Legon (UG)	BA/MPhil/PhD Economics, PhD. Development Economics, MA Economic Policy Management, BSc/MBA/MPhil/EMBA/PhD. Finance, BSc/MBA/MPhil/PhD. Accounting, MSc. Tax Policy & Finance, BSc. Banking & Finance, MSc. Accounting &Finance, BSc. Insurance, BSc/MBA/EMBA/MPhil/PhD. Human Resource Management, BSc/MBA/MPhil Health Services Administration, BSc/MBA/EMBA/MPhil/PhD. Marketing, MSc. International Business, EMBA Project Management, EMBA. Entrepreneurship Management, MSc. Hospitality & Tourism Management, MSc. Logistics & Transportation Management,
3. Kwame Nkrumah University of Science and Technology (KNUST)	MSc. Business and Data Analytics., MPhil/PhD Agricultural Economics, BA/MPhil/PhD. Economics, MPhil/MSc/PhD. Agribusiness Management, BSc/MSc/Phil/PhD. Human Resource Management, BSc. Marketing/International Business, BSc Accounting/Banking and Finance, BSc/MSc/MPhil. Hospitality and Tourism Management, MSc/MBA/MPhil/PhD Marketing, MBA. Entrepreneurship and Business Management, MSc/MPhil. Procurement & Supply Chain Management, MBA/MPhil/PhD. Strategic Management and Consulting, MBA/MPhil/PhD. Human Resource Management, BA/MPhil/PhD. Management and Organizational Development, BSc/MSc/MBA/MPhil/PhD. Logistics and Supply Chain Management, MPhil/PhD. Accounting, MSc. Development Finance, MSc. Accounting & Finance, MSc/MPhil. Management and Human Resource Strategy, MSc/MPhil/PhD. Finance.
4. University of Cape Coast (UCC)	BEd/BSc/MPhil/PhD. Economics, BSc. Applied Economics, BSc. Economics with Finance, BSc/PhD. Agricultural Economics, BEd/BCom/PhD. Management, B.Ed. Accounting with Management, BEd. Management with Accounting, BSc. Hospitality Management, BSc. Tourism Management, BSc. Mathematics with Economics, BEd/BCom/MCom/MBA. Accounting, BCom/MCom/MBA/PhD. Finance, BCom/ BSc/MBA. PhD. Procurement & Supply Chain Management, BCom/MCom/MBA/PhD. Marketing, BCom/BCom/MBA. Human Resources Management, BCom Entrepreneurship with International Business, PhD. Business Administration, MCom/PhD. Project Management, MBA/PhD. Entrepreneurship, MPhil. Public Policy & Management.
5 University of Development Studies (UDS)	BSc. Finance and Economics, MBA/PhD. Accounting, MBA/PhD. Finance, MBA Health Administration, MBA/PhD. Procurement & Supply Chain Management, MSc/MPhil/PhD. Economic Development Policy, MSc. Accounting & Finance, MSc/PhD. Entrepreneurship and Innovation, PhD. Human Resource Management, MSc/PhD. Development Finance
6. Ghana Institute of Management and Public Administration (GIMPA)	MSc. Financial Economics, MSc. Energy Economics, BSc. Procurement, Logistics & Supply Chain Management, BSc/MBA Finance, MSc. Economics Policy, Doctor of Management, BSc/MBA. Accounting, MSc. Accounting and Finance, BSc. Business Administration, MSc/MBA. Marketing, MBA/MSc. Human Resource Management, MSc/MBA. Supply Chain Management, MSc. Project Management, MSc. Development Finance, MBA. Project Management.
7 Central University	BSc/MPhil. Economics, BSc. Accounting, BSc/MBA. Human Resource Management, BSc/MBA. Marketing, BSc/MBA. Agribusiness, BA. Environmental & Development Studies, MPhil. Development Policy, MBA Finance, MBA Project Management.

8 Methodist University (Ghana)	BA Economics, BBA/MBA Accounting, BBA Banking & Finance, BBA/MBA Human Resource Management, BBA Management Studies, BBA/MBA Marketing, MA Entrepreneurship, MA Small Business Management, BSc/MSc. Procurement & Supply Chain Management, MBA Finance, MSc Accounting & Finance
9 Catholic University of Ghana (CUG)	BSc. Economics, BSc/MBA Accounting, BSc/MBA Marketing, BSc. Management & Organizational Behavior, BSc Banking &Finance, BSc/MBA Human Resource Management, PhD. Business Administration, PhD. Management Studies
10 Accra Institute of Technology (AIT)	BSc. E-Business/Commerce, BSc Accounting & Finance, BSc/MSc. Human resource Management & Information Technology, BSc Banking & Finance and Information Technology, BSc Marketing & Information Technology, BSc Entrepreneurship & Information Technology, BSc Accountancy, BSc Finance, BSc Marketing. MSc/PhD. Business Administration, MA Project Management
11 Ho Technical University (HTU)	BSc Economics & Innovation, BSc Accounting, BSc Financial Services, BSc Procurement & Supply Chain Management, BSc Management & Secretarial Studies, BSc Marketing & Information Technology, BSc Accounting & Taxation, MSc Hospitality & Tourism Management.
12 Accra Technical University	BTech Accounting & Finance Analytics, MTech Business Administration & Management, BTech Banking & Finance, BTech/MSc. Marketing, BTech Logistics Management.

Courses in Mathematics Required for EBA Studies

Figure 1 presented the main mathematics courses that are studied by EBA students prior to, and during, their undergraduate studies in Ghanaian Universities. Specifically, they take college-level Algebra, Geometry, Trigonometry, Calculus, Statistics and Probability, as well as Quantitative Methods, Mathematics for Economists, Mathematics for Business, Operations Research (Optimization Techniques), and Numerical Analysis. These courses lay the foundation for students' understanding of concepts underlying many of their undergraduate EBA courses. Various EBA courses require critical thinking and analysis, logical reasoning, problem-solving and knowledge dissemination/sharing. To excel in their academic work (and professional careers) in EBA courses/fields, students need to utilize their critical thinking and analysis skills, and knowledge of mathematical concepts/theorems and techniques from the various mathematics courses that they take in their undergraduate EBA programmes.

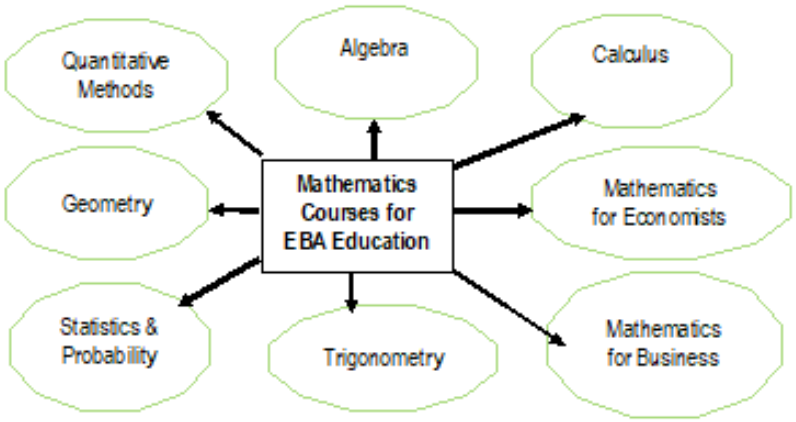


Figure 1. Main Mathematics Courses for Undergraduate EBA Studies

Analysis Of Major Undergraduate Eba Courses Requiring A Strong Mathematics Background

Figure 2 showed 8 major undergraduate Economics courses in Ghanaian universities that explicitly require students to possess a strong prior mathematics background. Economics "requires significant use of mathematics" (Moreno-García, et. al; 2019 p.1) because mathematics helps academics and professionals to understand economic processes and phenomena and its "tools are the basic instruments of economics" (Bulut, 2025 p. 22). for analyzing the complex relationships among economic variables. (Bulut, 2025). Thus, mathematics has undoubtedly become "an indispensable tool for understanding, modeling, and predicting economic events" (Bulut, 2025 p.26); and its usage "in economics, to a certain extent of course, is both unavoidable and necessary" (Hewage, 2020 p.153).

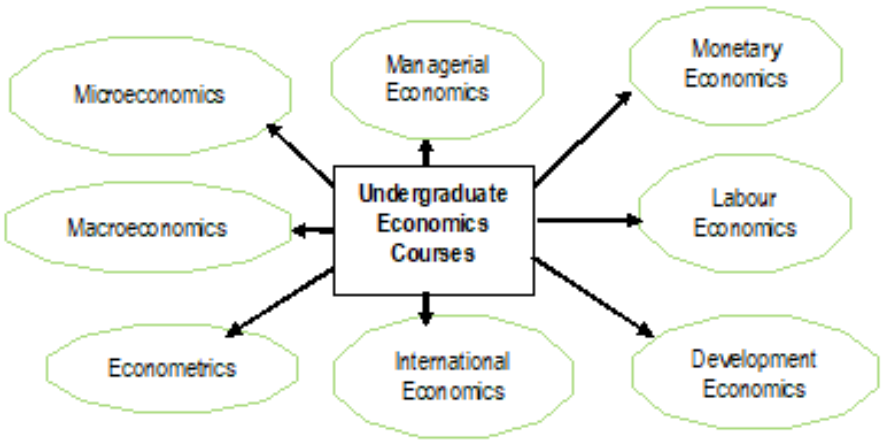


Figure 2. Major Undergraduate Economics Courses Requiring Mathematics

Figure 3 showed 10 major undergraduate Business Administration courses in Ghanaian universities that explicitly require students to possess a strong prior mathematics background. Students require critical reasoning, logical analysis and data-driven decision-making skills to excel in undergraduate business administration courses. They develop much of these skills from their prior mathematical courses (notably: arithmetic, geometry, algebra, probability, and statistics). In addition, they require grounding in the use of mathematical concepts, tools and techniques.

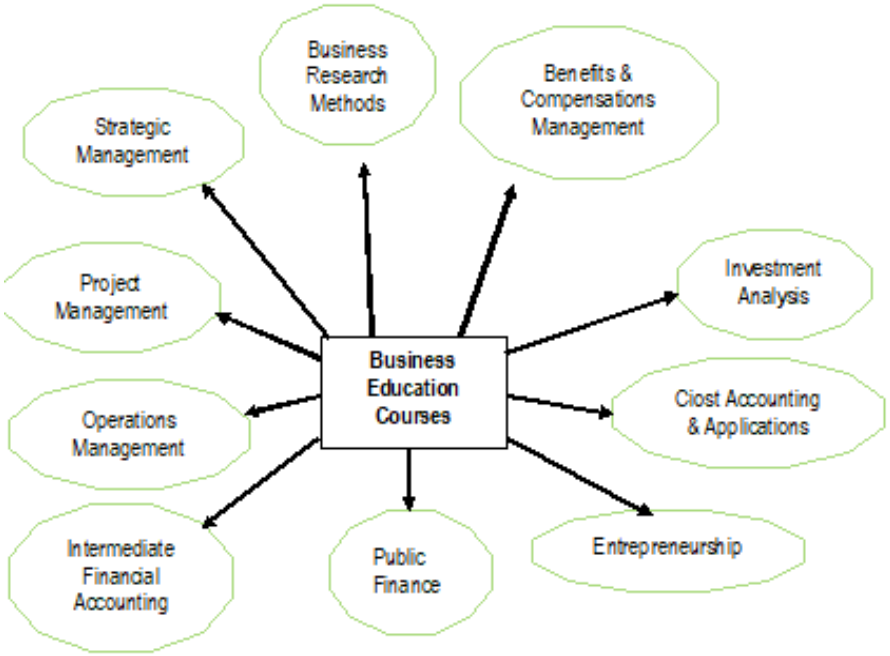


Figure 3. Main Business Education Courses Requiring Mathematics

Research Question (RQ): What is the relevance of pre-tertiary and undergraduate mathematics courses in undergraduate EBA education?

To answer the RQ, 8 major undergraduate Economics courses and 10 major undergraduate Business Administration courses are analyzed herein.

A. Analysis of Major Undergraduate Economics Courses

i. Microeconomics

This undergraduate EBA course builds students' knowledge and understanding of economic concepts and ideas regarding mechanisms by which economic agents (households, firms, and government) allocate resources for the production and distribution of products and services to satisfy consumers' needs and wants. Topics that are covered in this course typically include Utility/Consumer theory, Economic systems, Demand and supply, Production theory, Cost theory, Market structures, Welfare economics, and Information asymmetry and signaling. For students to effectively understand and apply concepts that these topics teach, they need to have a good grounding in linear algebra, geometry (particularly coordinate geometry), and calculus. For instance, determination of market equilibrium requires drawing graphs (learned in geometry) and systems of linear equations (learned in algebra). Specifically, utility maximization, production maximization, profit maximization, and cost minimization require the utilization of functions from algebra and differentiation from calculus while determination of consumers' and producers' surpluses require the use of integration from calculus. Similarly, students utilize their logical and critical thinking skills acquired in geometry, statistics, and algebra to present and analyze microeconomic data in tables and graphs, as well as interpret the results. Also, they need to use mathematical models (e.g. functions from algebra), statistical methods (e.g. mean and standard deviation), and probability distributions (e.g. Poisson distribution, binomial distribution, normal distribution) to analyze economic phenomena and/or to test economic hypotheses. Furthermore, students use their knowledge in Mathematics for Business (which involves the application of mathematical concepts in algebra, arithmetic, calculus and statistics to business), Quantitative Methods (i.e. the use of quantitative techniques in business decision-making, statistical analysis and results interpretation) and Mathematics for Economists to analyze and solve microeconomic problems (such as optimizing outputs, costs, revenues, profits, consumer's utility, determining equilibrium output and price, etc.).

ii. Macroeconomics

This undergraduate EBA course typically covers topics such as Circular flow of income, Business cycles, National income accounting, Aggregate demand and aggregate supply, IS-LM model, Fiscal and monetary policies, Population, Inflation, Unemployment, Migration, Foreign exchange, and international trade and payments. Many economic concepts in this course require critical and analytical thinking which mathematical tools and procedures provide. Specifically, linear algebra, geometry, statistics, and calculus provide an essential "framework for analyzing macroeconomic phenomena" (Prieto, 2021 p.12) for a country or group of countries, and for formulating "government macroeconomic policies" (Kahn, 2021 p.1), Students need to utilize their knowledge of mathematical models (from algebra, geometry, and differential calculus) to clearly understand the behaviour of economic variables such as inflation, money demand and supply dynamics, monetary and fiscal policies targeting and implementation, gross domestic product (GDP), exchange rate dynamics, international trade and payments dynamics, and unemployment. Knowledge of basic algebra and manipulating algebraic expressions are required to grasp national income accounting concepts, perform calculations on gross domestic product, and determine the equivalences of the three approaches (namely: product, income and expenditure approaches) to national income computation. Also, students need to use differentiation from calculus as well as functions and system of equations from algebra and graphs from geometry to comprehend and appreciate macroeconomic concepts such as IS-LM model as well as Phillips curve and inflation expectations so as to efficiently (i). determine the interest rate and aggregate output in an economy (given a fixed price level), (ii). evaluate the usefulness and/or effectiveness of monetary and fiscal policies on the economy, (iii). analyze the inflation-unemployment relationship, and (iv). perform macroeconomic forecasting. Furthermore, students need to use the knowledge they acquired from Mathematics for Business, Mathematics for Economists and

Quantitative Methods to model and analyze macroeconomic problems/phenomena and then proffer solutions to them.

iii. Managerial Economics

This undergraduate course involves the application of economic concepts, principles and methods to formulating, analyzing and solving business problems. It sharpens students' analytical skills and enables them to learn and utilize various techniques grounded in mathematics and economics to solve business problems relating to the production and distribution of goods and services and their attendant revenues, profits, and business strategies. Typical topics for this course include utility theory, demand & supply analysis, production and costs analysis, market structures, pricing decisions & policies/practices, input-output analysis, decision tree analysis, employment and unemployment, business cycle, and foreign direct investment. This course draws heavily on the mathematical tools and procedures as well as the critical thinking, as well as their analytical and problem-solving skills that students acquired from their prior mathematics courses. Specifically, students require knowledge of mathematical modeling and systems of equations from algebra and graphs from geometry to understand, appreciate analyze, and solve business problems relating to demand and supply, production and costs analysis, employment and unemployment, and market structures. They also need to utilize their knowledge and skills of differentiation and integration from calculus to solve business problems relating to utility maximization as well as production, costs and pricing decisions. Similarly, they need knowledge of matrices from algebra to perform input-output analysis; and knowledge of partial fractions to forecast market trends. Furthermore, students require knowledge of arithmetic to ensure accuracy of in their calculations on the various topics in this course. Thus, students who have weak algebra, calculus, geometry, and arithmetic backgrounds will struggle to cope with this course. In addition, students require knowledge of descriptive and inferential statistics and probability distributions to analyze data in this course and interpret the results.

iv. Monetary Economics

This undergraduate course, also dubbed Monetary Theory, teaches students to apply monetary theories and principles to solve monetary economic problems. Students typically utilize analysis tools such as graphs and economic models. They use their knowledge in algebra and arithmetic to understand and analyze banks' credit creation process and perform the calculations involved in foreign exchange rates determination. They also need algebra and geometry to understand the theory of asset demand, money demand theories, the IS-LM framework for money market and goods market equilibrium determination, and for aggregate demand and supply analysis. Specifically, students need to use their knowledge of ratios from arithmetic, functions, and equations from algebra as well as graphs from geometry to clearly understand the theories (and models) of money demand (such as the Liquidity Preference Theory, the Baumol-Tobin model and the Cagan model) which explain the extent to which changes in interest rates affect the quantity of money demanded. They also need to use their knowledge of differentiation from calculus, linear equations from algebra, graphs from geometry as well as probability distributions and stochastic processes from probability to understand uncertainties (and/or changes) regarding monetary and fiscal variables as they analyze money demand and money supply, foreign exchange rates, inflation rates, interest rates, as well as effectiveness of monetary and fiscal policies. Furthermore, students use mathematical models to analyze foreign exchange rates (forex) dynamics and how monetary and fiscal policies affect the forex (Sun, 2022). They also require knowledge of statistics to analyze monetary economic data.

v. Labour Economics

This undergraduate course enables students to utilize analytical tools learnt from mathematics and microeconomic theory to analyze society's development, allocation and reward of human resources as well as solve labor-related problems. Typical topics for this course are Labour supply and demand analysis, Labour market institutions and policies, Wage differentials, Monopsony, Cobweb model, Discrimination, Labour migration, Labour unionism, Labour market investments, Labour problems, Labour mobility, and Unemployment. Students use their knowledge in arithmetic, algebra, calculus, statistics, and geometry to understand and perform labour supply and demand analysis, unemployment, labour market investments, monopsony and Cobweb model in this course. Specifically, they need to draw (and analyze) diagrams for labour

demand and supply, monopsony, minimum wage legislation, income tax analysis, and for labour market equilibrium determination. They also need to use system of equations to calculate labour market equilibrium wage and labour quantity. They use differential calculus to analyze labour and capital productivities, maximize profits, and minimize costs. In addition, students use ratios to determine unemployment rate, isoquants, and marginal rate of technical substitution between labour and capital in the production process. Also, students utilize their knowledge of probability and statistics to analyze data in this course. Furthermore, functions, system of equations and matrices from algebra are used to model various labour economic phenomena (relating to labour supply and demand, labour market investments, relationship between unemployment and inflation, et cetera).

vi. Econometrics

This undergraduate course develops students' knowledge and analytic skills in quantitative methods and economic theory to enable them analyze complex economic problems. Several quasi-mathematical models that are employed in this course (such as Simple and multiple regression models, Autoregressive and distributed lag models, General linear model, and Simultaneous equation models) are often used to analyze complex economic problems; and students require very strong mathematical and analytical skills to utilize them. Students need to understand econometric concepts such as multicollinearity, heteroscedasticity, autocorrelation, test for their presence and solve them using numerical methods (which require strong mathematical skills routed in algebra, arithmetic, and calculus). These numerical methods include Generalized Least Squares (GLS) method of estimation, Cochran-Orcutt iterative method, 3-Stage Least Squares method, and Full Information Maximum Likelihood (FIML) methods. Students need knowledge of graphs from geometry to visualize econometric models, functions, and system of equations from algebra to formulate simple and multiple regression models, operations from arithmetic to correctly estimate parameters for system of equations and panel data models, and knowledge of descriptive statistics and inferential statistics (from statistics) as well as probability distributions (from probability) to perform significance testing and interpret the results. They can decompose complex econometric models using partial fractions from algebra; and estimate the regression models using Ordinary least squares (OLS) technique. Also, students need knowledge functions, system of equations from algebra, graphs from geometry, and differentiation from calculus to optimize profits, costs, revenues utility, and production functions/processes. They also need matrices from algebra to perform input-output analysis to gauge inter industrial dependency/relationships and interpret the results. Furthermore, they need to use their understanding of differential equations from calculus to compute Harrod-Domar model's dynamic multiplier, and knowledge of difference equations from algebra to understand and analyze Cobweb model and Harrod-Domar's multiple acceleration model in this course.

vii. International Economics

This course, often dubbed International Trade and Finance, utilizes international trade theories to explain economic phenomena. Major topics for this course include theories of international trade, free trade versus and protectionism, balance of payments and adjustment mechanisms, general equilibrium analysis of tariff, theories of exchange rate determination, global financial & trade institutions, foreign trade policies, global financial crisis, and developing countries' trade problems**.** Students rely on their knowledge of functions, tables and graphs to understand the theories of opportunity cost and comparative advantage, as well as for analyzing cartel profits, welfare effects of international joint ventures, dumping, foreign exchange determination, and subsidies (e.g., export subsidy for export goods producers, and domestic production subsidies for import-competing goods producers). Also, students need to utilize their knowledge of operations, ratios and percentages from arithmetic, equations and functions from algebra to understand the concepts of foreign exchange rate (forex) and terms of trade, calculate real forex, analyze balance of payments accounts of countries, calculate foreign trade multiplier, and compute the annual percentage rate of forward discount (or premium) of one currency against the other as well as calculate the exchange cross rate of one currency against another (when they are provided with the pertinent spot and forward rates). Similarly, students need to use their knowledge of mathematical proofs from algebra to evaluate the effectiveness of trade policies; and utilize descriptive statistics to analyze international trade data and interpret the results. Furthermore, students require knowledge of differential calculus to understand international trade theories and policies and analyze relationships between variables within the Heckscher-Ohlin theorem's context: e.g. i. relationship between changes in national factor endowments (of

capital and labour) and national output changes; ii. relationship between changes in national output (or goods' prices) and national factor price changes.

viii. Development Economics

This course, sometimes referred to as Economics of Growth and Development, teaches students fundamental economic growth and development concepts, theories/models, policies, approaches and issues to foster their understanding of the economy's development. Students also learn the development gap, determinants of economic growth and development, developmental institutions, national development planning, poverty and inequality and make assessments of health, education and infrastructural deliveries in this course. Arithmetic operations, ratios and percentages from arithmetic, functions from algebra, as well as tables and graphs from geometry are required for students to perform population growth analysis and development gap analysis (including poverty gap, income gap, education gap, urbanization gap, income-savings gap, and health gap analyses). Students need to use their knowledge of functions from algebra and mathematical modeling to analyze Lewis' structural change model, Harris-Todaro rural-to-urban migration model, as well as for performing returns to scale analysis (i.e. increasing, constant, and decreasing returns to scale analysis) in both Romer model and Solow growth model. Also, students need descriptive statistics and regression from statistics as well as probability distributions from probability to analyze both cross-sectional and panel data in this course and interpret the results. Furthermore, students require knowledge of differentiation and differential equations from calculus to analyze changes in economic growth, inflation, population growth, technological progress, capital accumulation, and national development programme investments; and duly get insights into economic development policy implications.

Table 2 provides a summary of mathematics courses vital for each of the 8 economics courses analyzed above. It shows that all the 8 economics courses analyzed require algebra, calculus, arithmetic, geometry, statistics, probability, Quantitative Methods, and Mathematics for Economists.

TABLE 2 MATHEMATICS COURSES NEEDED FOR UNDERGRADUATE ECONOMICS STUDIES

	Algebra	Calculus	Arithmetic	Geometry	Statistics	Probability	QM	ME
i. Microeconomics	✓	✓	✓	✓	✓	✓	✓	✓
ii. Macroeconomics	✓	✓	✓	✓	✓	✓	✓	✓
iii. Managerial Economics	✓	✓	✓	✓	✓	✓	✓	✓
iv. Monetary Economics	✓	✓	✓	✓	✓	✓	✓	✓
v. Econometrics	✓	✓	✓	✓	✓	✓	✓	✓
vi. Labour Economics	✓	✓	✓	✓	✓	✓	✓	✓

vii. International Economics	✓	✓	✓	✓	✓	✓	✓	✓
viii. Development Economics	✓	✓	✓	✓	✓	✓	✓	✓

QM=Quantitative Methods, ME=Mathematics for Economists

B. Analysis of Major Undergraduate Business Administration Courses

i. Investment Analysis

This undergraduate course teaches concepts, tools and techniques for analyzing investment ventures and portfolios. Students require knowledge of arithmetic, algebra, probability, geometry and statistics to understand investment analysis concepts (such as time-value of money, capital gains yield, current yield, expected rate of returns, liquidity, risk, capital asset pricing model (CAPM)), and perform calculations on them as well as calculations on investment appraisal methods (e.g. profitability index, internal rate of return, payback period, and net present value). Their proficiency in arithmetic, statistics and algebra is also required for financial modeling, portfolio theory, data analysis, financial forecasting as well as common-size financial statements analysis. Also, students use their knowledge of partial fractions from algebra to analyze growth models, forecast market trends, and financial instruments' fair values. Furthermore, students use ratios from arithmetic, equations (both linear and non-linear) and functions from algebra, graphs from geometry, as well as statistics and probability to perform technical and fundamental analysis of investments, risk analysis, evaluate portfolio performance in this course. Similarly, students utilize their knowledge of differentiation and partial differentiation from calculus to analyze effects of large and small changes, respectively, in investment variables (e.g., yield, returns, risks) on investment behaviour. Thus, mathematics provides the framework for evaluating investment opportunities and risks.

ii. Cost Accounting & Applications to Business

Students require strong foundations in geometry to draw and analyze graphs in inventory analysis. They also require arithmetic, algebra, and statistics to analyze costs, calculate optimal inventory levels, minimize inventory holding costs, and determine overstocking, stockout losses, and prepare cost and management accounting reports in this course and in their professional careers as cost and management accountants. Also, they require knowledge of statistics and mathematical models from algebra to forecast demand and analyze historical data in this course. Specifically, students need functions and linear equations from algebra to efficiently classify cost (into fixed costs and variable costs) and perform volume-cost-profit analysis and break-even analysis. They also need knowledge of percentages and weighted average from arithmetic and matrices from algebra to perform costing computations (notably: process costing, activity-based costing, and job-order costing). Furthermore, they need knowledge of differentiation from calculus to optimize costs; regression analysis from statistics to make cost estimations/projections, and probability-tree analysis from probability to perform decision analysis in this course (including calculating expected values and determining the optimal cost decision paths).

iii. Entrepreneurship

For this course, students utilize their knowledge of summations, ratios, and arithmetic properties from arithmetic, as well as functions and system of equations from algebra to understand concepts such as financial ratios, production function, cost function, profit function, and revenue function. They use tools such as matrices, linear programming and dynamic programming from algebra, differentiation from calculus, and graphs from geometry to optimize outputs, revenues, costs, and profits. Also, students need to use their knowledge of statistics, arithmetic and probability to perform break-even analysis, investment appraisal calculations (e.g. NPV and IRR), calculate entrepreneurial innovation metrics, as well as perform market data analysis, financial statements analysis and interpretation, materials planning, demand forecasting, and risk analysis. Furthermore, they need to

use their knowledge of probability-tree analysis and hypothesis testing from probability to analyze business decisions (such as calculating the expected values of investment-decision paths and determining the optimal path) and test business hypotheses.

iv. Intermediate Financial Accounting

This undergraduate course equips students with skills and knowledge to prepare as well as analyze budgets and financial statements, and perform financial forecasting and financial ratios computation for organizations. These tasks undoubtedly require students' logical reasoning and understanding of mathematical tools and principles from arithmetic, algebra, probability, and statistics. Specifically, students require knowledge of ratios, addition, subtraction, multiplication, and percentages from arithmetic to accurately calculate cost of goods sold, bad debt, financial ratios, depreciation, income taxes, fixed costs and variable costs, as well as balance accounts and journal entries. Also, students need to utilize arithmetic and statistics to analyze historical data and balanced scorecards, as well perform common-size financial statements analysis in this course. Furthermore, students need knowledge of percentages and weighted averages from arithmetic to perform inventory valuation; they also need linear equations from algebra to compute accumulated depreciation expenses. Similarly, students need knowledge of graphs from geometry to analyze inventory reorder level, maximum and minimum stock levels; and they need knowledge of differential calculus to optimize reorder quantities and order lead times.

v. Operations Research

This undergraduate EBA course introduces students to tools and methods for formulating and analyzing stochastic and deterministic models to solve business problems. These methods include decision tree analysis, linear programming (LP), network analysis, simulation, integer programming (IP), transportation and assignment problems, minimum cost flow problem, and queueing theory. Students require knowledge of functions and inequalities from algebra, tables and graphs from geometry and ratios from arithmetic to formulate as well as solve LP problems. They need to utilize tables as well as logical and analytical reasoning from mathematical proofs in algebra to formulate transportation problems and their attendant tableau, analyze them to find both the initial feasible solution and the optimal solution. Also, for students to understand, analyze and solve assignment problems, they need to use their knowledge of tables and arithmetic operations (subtraction, addition, multiplication and division) irrespective of whether they use Hungarian Method or Trial and Error method. Similarly, for each integer programming problem, they need to use their knowledge of tables and arithmetic operations to formulate the appropriate integer programming model; and then solve it. Also, students use their knowledge of graphs from geometry, probability distribution from probability to construct decision trees for projects (or business scenarios), and compute the probability distribution and expected value for each path, and then calculate the expected value for the entire project/scenario. In addition, students need to utilize their knowledge of arithmetic, geometry, probability, and statistics to draw network diagrams and then analyze them to determine the critical path, variance of the project length and probability of completion earlier (or later). Furthermore, knowledge of numerical analysis, functions from algebra, integration from calculus, and hypotheses testing from statistics and probability are required to understand the concepts of simulation, queueing theory and probability density function, as well as generate and test random numbers.

vi. Business Research Methods (BRM)

This undergraduate course acquaints students with research tools and techniques for social research, in general; and equips them with competencies and skills for planning and undertaking their researches individually or in teams. Students learn to perform the tasks involved in the entire social research cycle; which typically include research topic selection, research conceptualization, problem statement, identification of research objectives, research questions and/or hypotheses, theoretical and empirical literature reviews, conceptual framework specification, research design, sampling, data collection and collation, data analysis, as well as presentation, interpretation and discussion of results, and proffering recommendations. They also learn how to write project proposal, as well as the abstract and the citations/references (both in-text citation and reference citation). They utilize their knowledge of mathematics in the conceptualization, planning and execution of their research projects. For example, students use their analytical skills as well as knowledge of functions and variables from

algebra, number system and arithmetic operations (e.g., addition, multiplication) from arithmetic, frequency distribution tables from statistics and graphs from geometry to understand variables classification as well as data collection, collation, and results presentation techniques. Their knowledge of graphs from geometry is utilized to draw Gantt charts for project schedules. They also utilize their knowledge of sampling techniques from statistics to guide the selection of samples for data collection. Students also use their knowledge of measures of dispersion (e.g. variance, range, standard deviation) and central tendency (e.g. mode, median, mean) as well as statistical methods (e.g. regression, correlation) from statistics, probability distributions (such as F, student's t, normal, and chi-square distributions) from probability, as well as hypotheses testing techniques from both statistics and probability to analyze business research data. Furthermore, they use their knowledge of statistics and probability to interpret the results of their business researches.

vii. Project Management

This course teaches students the concepts, tools, methodologies, and techniques relating to project "initiation, planning and design, execution, monitoring and control, and closure" (https://www.atlassian.com, n.d.). It also guides them on the processes and procedures for achieving a project's goals within the "set scope, time, quality and budget standards" (Team AdaptiveWork, 2021). Students require knowledge from arithmetic, probability, geometry, and statistics to draw network diagrams and then analyze them to find the earliest start and latest finish times of each activity, the project's total duration, and the critical path, as well as perform schedule compression, calculate the standard deviation of project's length, and probability of getting the project completed earlier (or later). Similarly, students require knowledge of tables and graphs to use project management tools such as Work Breakdown Structure (for developing and sequencing project activities' list), Gantt charts for project planning and monitoring) and Network Diagram (for estimating project duration and determining critical activities). Also, project costing and cost-benefit analysis of projects require knowledge of arithmetical operations (addition, subtraction, division and multiplication). Students also require knowledge of arithmetic, algebra, probability, geometry, and statistics to understand project risk analysis concepts and calculate a project's internal rate of return, payback period, and net present value. Their proficiency in arithmetic, statistics and algebra is also required for financial modeling, and data analysis for projects. For students to perform earned value analysis for projects such as calculating the project's cost performance index, schedule variance cost, and cost variance, they need knowledge of ratios and arithmetic operations. Similarly, they need knowledge of arithmetic, algebra, geometry, statistics and probability to perform project risk analysis (e.g., using regression analysis, or sensitivity analysis technique) to gauge the risks that have the "most potential impact on project outcomes" (Project Management Institute, 2021 p. 284). Also, students require knowledge of differentiation from calculus to analyze and optimize investments, costs and schedules of projects. Furthermore, students use their knowledge of graphs from geometry and probability distribution from probability to construct decision trees for projects, compute the probability distribution and expected value for each path, and then calculate the expected value for the entire project/scenario.

viii. Benefits & Compensations Management

In this course, students learn compensation determinants, theories, policies and strategies, as well as compensation package components, collective bargaining, and employee performance measurement schemes. Students need to utilize their knowledge of logic from algebra to understand the income tax structure. Also, they use their knowledge of frequency tables from statistics to understand and develop salary ranges for employees. They also need knowledge of percentages and arithmetic operations (especially addition and subtraction) to calculate allowances and deductions, and then prepare employees' payroll showing the gross salary and net salary for each employee. Similarly, students need analytical skills from algebra as well as arithmetic operations to perform payroll audits. In addition, knowledge of arithmetic, algebra, geometry, and statistics is required for compensation-related data collection and collation (into tables and graphs), as well as data analysis and interpretation of results. Furthermore, students utilize knowledge of regression and correlation from statistics, graphs from geometry, probability, as well as descriptive and inferential statistics to analyze compensation data, interpret the results and proffer recommendations in compensation-related research e.g., research on the impact of compensation packages on employee performance. Similarly, students require knowledge of differential

calculus to analyze the impact of benefits and compensation policy changes on productivity and employment level.

ix. Strategic Management

This course teaches the concepts, tools, procedures, and techniques for strategic thinking, diagnosing complex strategic organizational problems, proffering actionable time-bound recommendations to them, as well as justifying the recommendations. It also sharpens students' critical thinking and analytical skills and develops their knowledge in formulating, analyzing, and implementing organizational strategies. Students require to utilize their knowledge of descriptive statistics as well as regression analysis from statistics as well as probability distributions from probability to determine how customer satisfaction affects production and sale volumes, and how national economic and political conditions such as inflation, unemployment, and political instability affect a firm's sales volume, revenue, and profit. Also, students require arithmetic operations, functions, and algebraic equations to effectively perform analysis of new entrants' threat, rivalry among competing firms, as well as the powers of suppliers, substitute products, and buyers (i.e., using Porter's 5-forces model). Percentages and ratios from arithmetic and graphs from geometry are required to analyze the financial performances of competing firms (in terms of market shares, changes of sales revenues, net incomes, gross profits, and net profit margins); as well as analyze their financial capabilities/ratios (e.g. earnings per share, return on net sales, current ratio and inventory turnover ratio. In addition, students require knowledge of ratios, percentages from arithmetic and graphs from geometry to perform common-size and trend analyses of firms' financial statements, as well as balanced scorecard analysis and corporate restructuring costs and benefits analysis. Also, for efficient allocation of resources, risk assessment as well as financial and operational forecasting for organizations, students require knowledge of arithmetic operations, ratios, percentages from arithmetic, mean, mode, standard deviation, and regression from statistics, graphs from geometry, and probability distributions from probability. Furthermore, students require knowledge of differentiation (differential equations) and partial derivatives from calculus to (i). analyze strategic interactions among firms, (ii). optimize capacity planning, pricing, and investment decisions, (iii). analyze the impact of a firm's different advertising schemes on its sales volume.

x. Public Finance

This course develops students' knowledge of government's role and intervention in an economy as well as how its taxation systems and expenditure programs impact citizens' behaviour and welfare. It builds students' critical thinking skills for public sector financial administration. Students require knowledge of percentages and arithmetic operations from arithmetic and graphs from geometry to perform budget analysis (i.e. budgetary allocations analysis). Also, they require knowledge of graphs from geometry, percentages and arithmetic operations from arithmetic to perform expenditure analysis of government parastatals. In addition, knowledge of functions and equations from algebra, differentiation from calculus, descriptive and inferential statistics from statistics, and probability distributions from probability are required to understand public goods and externalities and perform resource sustainability and marginal analyses on them. Students also utilize their knowledge of ratios and percentages from arithmetic, system of equations, functions from algebra, graphs from geometry and data analysis skills from statistics to analyze tax incidences on suppliers/producers and consumers, calculate tax multipliers, and determine the impact of taxation on employment, price and output levels in an economy. Furthermore, in analyzing market failures, students need to use their knowledge of graphs and percentages to understand subsidies and price control mechanisms (e.g., minimum price legislation, maximum price legislation); and they need arithmetic, geometry, algebra, calculus, probability, and statistics to conduct public finance research; for instance, to determine the effect of changes in public debt on foreign exchange and interest rates behaviour in an economy.

Table 3 provides a summary of mathematical courses required for the 10 Business Administration courses analyzed above. It shows that all the 10 business administration courses analyzed require algebra, calculus, arithmetic, geometry, statistics, probability, Quantitative Methods, and Mathematics for Business.

TABLE 3. MATHEMATICS COURSES REQUIRED FOR UNDERGRADUATE BUSINESS ADMINISTRATION STUDIES

	Algebra	Calculus	Arithmetic	Geometry	Statistics	Probability	QM	MB
i.Investment Analysis	✓	✓	✓	✓	✓	✓	✓	✓
ii.Cost Accounting & Applications to Business	✓	✓	✓	✓	✓	✓	✓	✓
iii.Entrepreneurship	✓	✓	✓	✓	✓	✓	✓	✓
iv.Intermediate Financial Accounting	✓	✓	✓	✓	✓	✓	✓	✓
v.Operations Research	✓	✓	✓	✓	✓	✓	✓	✓
vi.Business Research Methods (BRM)	✓	✓	✓	✓	✓	✓	✓	✓
vii.Project Management	✓	✓	✓	✓	✓	✓	✓	✓
viii.Benefits & Compensations Management	✓	✓	✓	✓	✓	✓	✓	✓
ix.Strategic Management	✓	✓	✓	✓	✓	✓	✓	✓
x.Public Finance	✓	✓	✓	✓	✓	✓	✓	✓

QM=Quantitative Methods, MB=Mathematics for Business

CONCLUSION AND RECOMMENDATIONS

This study utilized reviews of extant literature, as well as the syllabuses and recommended textbooks of 12 universities in Ghana to explore the relevance of mathematics in undergraduate EBA education. It revealed that students need mathematical tools and techniques to grasp and apply EBA concepts to solve real-life problems;

and those who want to specialize in options of undergraduate EBA programmes that have much mathematical content (notably: economics, accounting, and finance), need to have strong grounding in basic and advanced mathematical concepts, tools and techniques to succeed.

The following recommendations are, therefore, proffered:

- Since "universities in Ghana do not offer any bridging Mathematics course(s) to help students who have weak mathematics backgrounds from senior high school" (Avevor, 2025 p. 1038), tutorial sessions for mathematics courses that undergraduate EBA students take should be extended for about one hour per week.
- Universities should make grade C6 on WASSCE's Elective Mathematics and Core Mathematics as the minimum math requirement for undergraduate EBA students who want to specialize in math-dominant options such as economics, accounting, and finance.
- Syllabuses for EBA courses should emphasize applications of mathematical concepts, tools and techniques to solving economics and business problems. This will undoubtedly foster students' perception of the relevance of mathematics in those fields.
- Lecturers (and teaching assistants) should refine their pedagogical techniques to make their lessons (and tutorial sessions) practical, interesting, interactive and student-centred.
- Researchers may consider undertaking exploratory or empirical research on students' assessments of the importance of mathematics for undergraduate EBA education.

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