esade

Calculus & Algebra

Bs in Business and Artificial Intelligence

Syllabus

6 ECTS

BBAI, 2025-2026

Barcelona, September 2025

Table of contents

1. Introduction and Course Description

Mathematics is an essential tool to analyze information (both quantitavely and qualitatively), to create, assess, and interpret models that explain our current world and, overall, to develop structured reasoning processes.

We are living a digital revolution where quantitative data management and analysis have become not only key assets, but absolute necessities within any business field. Now more than ever, the world needs people with strong abstract reasoning abilities, capable of developing and applying theoretical models and tools to any business situation.

Calculus and Algebra are the foundations of logical and abstract thinking, and thus they are the foundations of the language spoken by Machine Learning algorithms. Therefore, it is of outmost importance that students at the BBAI will be fluent in these subjects.

The course on Calculus and Algebra represent a step forward on the path of Mathematical reasoning. Students have been learning concepts and procedures on these subjects throughout their academic lives, and now it is time to provide them with the necessary tools to cope with new, changing conditions that need a skillful use of Mathematical methods and tools. It is not about "following a formula" but to be confident about the right steps to do to solve new problems. Under this new scope, students will be required to analyze logically the situation, to assess critically the practical usefulness and interpretation of Mathematical results, and to connect them to applications in Economics and Statistics. Last but not least, the students will not only discuss practical applications but also the theoretical background that supports them. In short: when, why and how Calculus and Algebra work.

Prerequisites

It will be assumed from the very first day of the course that students have a strong background in Mathematics; in particular, students will be fluent at dealing with the following basic Mathematics and Statistics topics:

1) Basic Set Theory; intersection, union and complementary.
2) Fundamental on equations and inequalities; definition, resolution, and geometric interpretation.
3) Fundamentals of functions on one variable; definition, domain, range, graph of basic functions.
4) Limit of a function; concept, basic calculation, and geometric interpretation.
5) Continuity function; definition, calculation, and geometric interpretation.
6) Differentiability of a function; definition, calculation, and geometric interpretation.
7) Integration of functions on one variable; definition, calculation, and geometric interpretation.

8) Fundamentals of matrices; definitions and basic properties and operations.

9) Mean And Variances From Frequency Tables; definitions and basic calculations.

10) Basic probability; counting possibilities; Laplace Formula and basic applications.

Students who have not shown a good level of knowledge on the previous topics will not be considered fully capable of following the course at the regular pace, and thus they will not be allowed to take the final exams. See the section on assessment for further details.

2. Learning objectives and competencies

Among the core learning outcomes of the BBAI Program regarding Knowledge (RAK), Skills (RAS) and Competences (RAC), this course contributes to the following:

RAK3.   Define the main concepts and methods of Data Science and Programming to extract and manage information coming from data.

RAK4.   Determine Mathematical and Statistical methods that need to be applied to describe a specific context.

RAK5.   Describe algorithmic techniques and their main features.

RAK20. Identify the concepts and methods of Artificial Intelligence to design solution to Business problems.

RAS7.   Use concepts from Mathematics, Statistics, Artificial Intelligence, and Computing, to build data-based models.

RAS8.   Dialogue with diverse and interdisciplinary teams to develop an inclusive and perspective, respecting the principles of equality and nondiscrimination because of gender.

RAS10. Analize capacities, strengths, and weaknesses of oneself, to develop a continuous learning strategy.

RAS11. Examine the different parts of a problem to design a solution.

RAS12. Actively look for new opportunities to improve the job to be done.

RAS14. Synthesize relevant information to develop justifications and recommendations, based on previous analysis of a problem or an opportunity.

RAS15   Interpret the impact of business decisions on sustainability.

RAC18. Spread out information in an effective way.

RAC19. Facilitate cooperation as a way to reach team objectives.

In particular, upon successful completion of the course on Calculus and Algebra, students will be able to:

- Recognize and use Mathematical language fluently in appropriate situations (RAK3, RAK5, RAK20, RAS7, RAC18)
- Communicate, orally and in writing, the results found and the underlying justifications, in a Mathematically meaningful way (RAK3, RAK5, RAS7, RAS10, RAS14, RAC18)
- Prove statements, propositions, and theorems, as a way to foster analytic thinking and fact-based reasoning (RAK3, RAK4, RAK5, RAK20, RAS11, RAS12, RAS14, RAS15, RAC18)
- Find suitable Geometric interpretations of the problems to be solved and/or the solutions found (RAK4, RAS7, RAS10, RAS11, RAS12, RAS14, RAC18)
- Face new problems and situations and identify the right tools to cope with them, in order to build a well-founded solution (RAK4, RAK20, RAS7, RAS10, RAS11, RAS12)
- Be ready for the subsequent courses of the BBAI and beyond (RAS8, RAS10, RAC19)
- Apply the concepts and techniques learnt in an ethical manner (RAS8, RAS15, RAC19)

3. Course format and methodological approach

The course will be divided in 4 Units, each of them consisting of several Topics to be dealt with. The underlying concepts on each Topic will be acquired by the students through off-class work, Lecture sessions and Practice sessions.

Off-class work

It is expected that students devote to off-class work at least twice the amount of time spent in class, on Lecture and Practice sessions.

It is required that students work previously on the theoretical concepts underlying each Topic, and keep working after each session, until the end of the Topic, and beyond.

Topics and Units are designed in a subsequent way, so the best way to cope with a given Topic is to make sure that the level of theoretical and practical knowledge on the previous ones are good enough.

The first Unit of the course, as set in the next section, will be dealt with by students as off-class work, and the level of understanding about that Unit will be assessed orally, during the Mid-terms week (October 15th, 9:00 to 14:00). See section 5 for further details.

Lecture sessions

Assistance to Lecture sessions is mandatory; any absence from any Lecture session will be considered unjustified, unless BBAI Program Management explicitly justifies them to the Teaching staff.

Lecture sessions will be the place to solve student's doubts and to discuss further issues related to each Topic. Even though Lecture sessions are designed as master classes, students are encouraged to actively participate during these sessions, to make sure they can follow that session and the next ones. Nevertheless, students must be aware that sometimes the concepts are difficult to get at first, second or even third sight, so they should come to class being confident that most of the work has been / will be done during off-class sessions.

Lecture sessions will be founded on the previous off-class work done by the students and thus they will not be a mere repetition of the materials shared.

Lecture sessions will last 60 minutes.

Practice sessions

Assistance to Practice sessions is mandatory; any absence from any Practice session will be considered unjustified, unless BBAI Program Management explicitly justifies them to the teaching staff.

During Practice sessions the class will be split into three different groups, where students will work in small teams to deepen their knowledge on each Topic. Practice sessions may include some guided exercises to provide students with new theoretical skills, or to apply them in a different way than that shown during the Lecture sessions.

Practice sessions represent the opportunity for the students to assess their level of understanding on each Topic, and to discuss and clarify any issues with their teammates and/or the Practice professor.

At the end of some Practice sessions students will be formally assessed about their progress on each topic. These assessments can take the form of a problem to be solved using pen&paper, a problem to be solved using Mathematical software, or a theoretical question to be proved / developed. See the section 5 for further details.

Practice sessions will start after a Lecture session and a small break of 10 minutes and will last 80 minutes.

Tutoring sessions

As an additional help, some online tutoring sessions will be organized, so that students can raise their questions and issues found during the course.

Tutoring sessions will be led by the Teaching staff, but these sessions will not be considered by any means in any of the course grading items, to guarantee that students can feel free to bring any doubts or learning needs they might face.

Assistance to Tutoring sessions is completely voluntary, but active participation and willingness to learn will be required. Tutoring sessions will be held on Tuesdays, between 17:30 and 20:00.

4. Course Contents

The contents of the Calculus and Algebra course are as follows:

Unit 1. Discrete Mathematics

The first Unit of the course will be learnt by students completely from off-class work (including, if necessary, tutoring sessions to answer specific doubts the students might have). This unit will cover the following topics:

- **Modular Arithmetic.** Integer numbers. Prime numbers. GCD and Euclid's Algorithm. Modular Arithmetic.
- **Introduction to Cryptography.** Basics of Cryptography. Private key Cryptography. Public key Cryptography. The RSA algorithm.

Unit 2. Foundations of Mathematical Thinking

This Unit recaps some basic concepts and procedures that will be used during the course, and consists of the following topics:

- **Basic Topology in $\mathbb{R}^n$.** Open, closed, bounded, and compact sets. Ball of radius r.
- **Proofs**. Basic definitions and rules of logic. Basic Mathematical Proofs.
- **Geometry**. Definition of Point, Line, Plane, and Hyperplane in $\mathbb{R}^n$. Trigonometric functions.

Unit 3. Linear Algebra

This is one of the two main Units of the course, and consists of the following topics:

- **Introduction to matrices**. Recap of basic definitions. Discussing systems of equations. Gaussian elimination. Geometric interpretation. Linear maps and matrix of a linear map. Kernel and Image of a linear map.
- **Matrix diagonalization and inner products**. Eigenvalues & Eigenvectors. Diagonalization. Dot product and Norm. Orthonormal bases. Eigenvectors and orthonormal bases. Quadratic forms: definition and classification rules. Geometric interpretation: quadratic forms in $\mathbb{R}^3$.

- **Vector spaces**. Definition of vector, operation, and linear combinations. General definition of Vector space and subspace. Spanning sets. Basis of a Vector space. Coordinate systems. Vector spaces and matrices. Basis change. Fundamental subspaces of a matrix. Projections. Geometric interpretation. Linking Algebra and Calculus.

Unit 4. Introduction to Multivariable Calculus

This Unit is the other main Unit of the course, and consists of the following topics:

- **Functions on $\mathbb{R}^n$**. Recap of functions on one variable. Limits and L'Hôpital's rule. The Epsilon-Delta approach to limits. Definition, continuity, and limits in $\mathbb{R}^n$. Level curves and geometric interpretation. Differentiation: partial derivatives, gradient vector, Hessian matrix. Directional derivatives.
- **Unconstrained optimization**. Recap of unconstrained optimization of one-variable functions. Unconstrained optimization of n-variable functions. Link to Taylor approximations, Quadratic forms, and Geometric interpretation.

5. Assessment

Faculty will assess students' correct use of concepts and theoretical models as well as their mastery of Mathematical notation achieved during the course. Both individual and team activities will be considered, by means of the following grading items:

Final Exam (FE)

There will be a final exam at the end of the course, which is subject to the general rules of the BBAI concerning final exams.

The final exam will be held on **December 15th, 12:30 to 15:30**, and will be graded on a scale between 0 and 10.

A minimum average grade of 4 points out of 10 on the final exam is required. If this minimum grade is not achieved, the final course grade will be the grade of the final exam.

Not attending the final exam will result in a final course grade of NP ("Not Presented"), unless the absence is formally justified by Program Management to the teaching Staff. Under this exceptional case, a new date will be set.

ESADE's Internal Regulations stipulate that, to be able to sit the final exams, students need to have attended at least 80% of the respective class sessions, between the first day of class and the date of the corresponding final exam; if the percentage is not reached, students will not be allowed to write the final exam, and the grade on it will be NP. All justified absences will not be considered when calculating the ratio.

Moreover, students will not be allowed to write the final exam if they have been absent for more than 50% of class sessions, irrespective of whether their absences were justified by Program Management or not. In such a case, their final course grade will be NP.

Students retaking the course without class attendance will attend the final exam on the same day as the rest of the class. For such students, the final course grade will be the grade on the final exam.

During the final exam students will be allowed to bring a formula sheet (one page) handwritten by themselves.

Oral exam (OE)

Next **October 15th, 9:00 to 14:00** (Mid-terms week), students will be assessed orally regarding Unit 1. The exam will include some theoretical questions and/or some exercises to be solved and explained to the audience and will receive a grade between 0 and 10 points.

To help students get ready for the Oral exam, during Practice sessions students will be required to answer some questions orally. The answers will be assessed, out of 1 point, according to their clarity and correctness. At the end of the course, the average of all the grades on these answers will be computed and added to the grade of the OE.

Class Participation and teamwork (CP)

Students are encouraged to participate in both Lecture and Practice sessions, but the focus will be on their level of commitment to their own learning process and that of their teammates. The grade on CP, out of 10 points, will be based on the sole opinion of the corresponding Practice sessions professor, who will consider, among other items, the following[1]:

- Class participation.
- Ethical and proper use of electronic devices.
- Punctuality.
- Team interaction.
- Willingness to learn by doing.

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[1] These items are shown in alphabetical order; no other meaning must be related to the order of appearance in this list.

Individual Assessment (IA)

At the end of some Practice sessions the students will be required to answer a problem (theoretical and/or practical) on the current Topic or any of the previous ones. The use of Mathematical software may be required on some IA.

Each IA will last about 10 minutes and will be graded on a scale between 0 and 3 points but, under special conditions, brilliant IAs could receive 3.5 points.

There will be two IA on Units 2, 3, and 4, but only the best result out of those two IA will be considered.

Absence from a Practice session will result in a grade of 0 points to the corresponding IA, being the absence justified or not[2].

At the end of the course, the average of the best IA grades will be computed and transformed into a 0-10 scale.

Written exercises (WE)

At the end of some Practice sessions the teams will be required to submit the work done; the grade, out of 10 points, will be assigned to each team member. The student in charge of writing and submitting the work done by the team will receive an extra grade, between -1 and $+1$ points, based on the quality of the justification and the clarity of the work submitted. At the end of the course, the average of all the grades on WE will be computed.

Course grade

Under the conditions specified in the previous sections, the following formula will be used to calculate G, the course grade of each student[3]:

$$G = \begin{cases} FE & \text{if } FE < 4 \\ MAX(0.85FE + 0.15CP \, ; \, 0.4FE + 0.2OE + 0.15(CP + IA) + 0.10WE) & \text{if } FE \geq 4 \end{cases}$$

To pass the course, G needs to be at least equal to 5 points out of 10.

Students having $G \geq 10$ will be candidates to receive a distinction with honors on the course.

Evaluation of the final grade will consider any applicable policies set forth within the course or at Program level; in particular, please take a close look at the Program's honor code at the end of this document.

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[2] Nevertheless, in case a student has justified absences on the two IA of a given Unit, the final average grade of IA will not consider the grade on that Unit.

[3] The ESADE Faculty can decide to use another formula, as long as the resulting G is greater than or equal to the one obtained using the formula described in this document.

Retake exam (RE)

Students with a course grade, G, calculated according to the previous formula, being less than 5 out of 10 will have one last opportunity to pass the course, by retaking a final exam on the four Units in January 2026.

The final grade on the RE must be greater or equal than 4 points, and G, the course grade, will be calculated according to the previous formula, substituting FE by RE[4]:

To pass the course, the new value of G needs to be at least equal to 5 points out of 10.

Not attending the final exam will result in a final course grade of NP ("Not Presented")

During the retake exam students will be allowed to bring a formula sheet (one page) handwritten by themselves.

6. Attendance and Etiquette

Students will be expected to be present in class **about 5 minutes before** the scheduled start time, to ensure sufficient time for settling in and registering attendance. The attendance of all students coming to the class 5 minutes or more after the scheduled start time will be marked as "Late", and that will count as a quarter of an unjustified absence.

The attendance of all students entering the class 15 or more minutes late after the scheduled start time will be marked as "Absent", and that will be considered an unjustified absence to the corresponding session.

If students display any of the following behaviors in class, they will be expelled immediately from the classroom and their attendance will be marked as "Absent" for the corresponding session with a warning that, if the behavior is repeated, they will be reported to Program Management for further disciplinary actions:

- Using any electronic device during the Lecture sessions, unless otherwise specified by the Teaching staff.
- Hindering the good development of the sessions, e.g., by talking disruptively, leaving the room without permission, or eating in the room.
- Using headphones or earphones in the room, during any session.
- In general, any behavior considered inappropriate by the Teaching staff.

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[4] As with the calculation of the final grade, the ESADE Faculty can decide to use another formula to calculate the final mark after the retake exam, as long as the resulting final mark is greater than or equal to the one obtained using the formula described in this document.

7. Faculty leading the course

Francesc Rossell, Coordinator of the course. After graduating in Mathematics at UPC a long time ago, Francesc discovered that his passion for Maths & Statistics could be extended to Finance, Business Administration, Teaching (he holds a Masters' degree on each of these fields) and even Coaching (he is a Professional Certified Coach and a member of the International Coach Federation). He combines teaching Mathematics, managing projects in Risk Management and Machine Learning (yes, Finance speaks ML too), and coaching people and high-performance teams. He also likes writing (the last book he wrote, in Spanish, can be purchased at https://shackletonbooks.com/inicio/325-el-infinito.html) and running, especially in the morning, because "Best decisions can come in the midst of a Marathon".

Francesc Rossell started teaching at ESADE in 2019, and is currently a Teaching Fellow of this Business School; together with his teaching duties, he is also in charge of coordinating the Capstone Projects of the MSc in Business Analytics and the Business Development Projects of the Executive MIBA, and the manager of the BMST.

Contact: francesc.rossell@esade.edu

Office hours: By appointment

Nil Agell, Practice Professor. Nil holds a BS degree in Mathematical Engineering in Data Science (UPF) and has focused his career on advanced analysis and modeling for decision-making. Nil's interest in innovation led him to complete, in 2024, a master's degree in Big Data and Artificial Intelligence, where he applied machine learning techniques to high-performance sports contexts.

Nil has worked at an electronic invoicing company as a data analyst across various areas of the organization, ranging from financial control to identifying opportunities for the marketing department, contributing to process optimization and the generation of strategic insights.

Since 2023, Nil has been a researcher at ESADE D3 (Institute for Data-Driven Decisions), participating in multidisciplinary projects on the application of network models for the representation and analysis of complex phenomena, with a special emphasis on the study of football. His contributions include the development of analytical models to enhance the understanding of collective dynamics in sports.

Nil Agell started teaching at ESADE in 2024, as a Practice Teacher in the BBA program, where he teaches Applied Maths and Statistics, thus combining his passion for Mathematics and Technology.

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Office hours: By appointment

9. Timetable

Unit	Date	Topic
0. Introduction	8/9/2025, 10:45 - 13:15	Course introduction. Topology
1. Discrete Mathematics	(off-class work)	Modular Arithmetic
	(off-class work)	Introduction to Cryptography
2. Foundations of Mathematical Thinking	10/9/2025, 8:00 - 10:30	Topology. Proofs
	15/9/2025, 10:45 - 13:15	Proofs. Geometry
	17/9/2025, 8:00 - 10:30	
	22/9/2025, 10:45 - 13:15	Geometry
	29/9/2025, 10:45 - 13:15	
	1/10/2025, 8:00 - 10:30	
3. Linear Algebra	6/10/2025, 10:45 - 13:15	Introduction to matrices
	8/10/2025, 8:00 - 10:30	
	15/10/2025, 9:00 - 14:00	Oral Exam. Unit 1
	20/10/2025, 10:45 - 13:15	Matrix diagonalization and inner products
	22/10/2025, 8:00 - 10:30	
	27/10/2025, 10:45 - 13:15	Vector spaces
	29/10/2025, 8:00 - 10:30	
	5/11/2025, 8:00 - 10:30	
4. Introduction to Multivariable Calculus	10/11/2025, 10:45 - 13:15	Functions on R^n
	12/11/2025, 8:00 - 10:30	
	17/11/2025, 10:45 - 13:15	
	19/11/2025, 8:00 - 10:30	
	24/11/2025, 10:45 - 13:15	Unconstrained optimization
	26/11/2025, 8:00 - 10:30	
	15/12/2025, 12:30 - 15:30	Final Exam - Units 1 to 4

Annex. The ESADE Honor Code

"I will not lie, cheat or steal to gain an academic advantage. I will respect all ESADE students, faculty and staff with my words and deeds."

The violations of the ESADE BBAI Honor Code include the following:

Lying: Lying includes knowingly communicating an untruth in order to gain an unfair academic or employment advantage.

Cheating: Cheating includes, but is not limited to, using unauthorized materials to complete an assignment; copying the work of another person; unauthorized providing of materials or information (e.g. proprietary course information) to another person; plagiarism; unauthorized providing of materials or information to another person during an exam. All communications, written, oral or otherwise, among students during examinations, are forbidden, as is the use of notes, books, computers, calculators, or other written material except when approved by the instructor.

Stealing: Stealing includes, but is not limited to, taking the property of another member of the ESADE community without permission, defacing or vandalizing the property of the ESADE Business School, or the misuse of ESADE resources.

Disrespecting others and showing unprofessional conduct: Disrespect for others includes treating all ESADE students, staff, faculty, and external contacts connected to the school without politeness and cordiality, using abusive language or physical violence.

Upon witnessing a violation of the Honor Code, a student has the **moral obligation** to inform the student whose conduct is believed to be in violation of the Code that the Code has been violated. Each member of the ESADE community, as a person of integrity, has a personal obligation to adhere to this requirement, both on campus and when representing ESADE off campus.

Failure to comply with the more explicit guidelines set forth by the Program's Rules and Regulations can also be considered as a breach of the Honor Code.

Violations of this agreement will be governed by BBAI Program Management which has the right to exercise any disciplinary action necessary in order to uphold the standards set forth herewith and in the Program's Rules and Regulations.