FOLIA 407

Annales Universitatis Paedagogicae Cracoviensis

Studia ad Didacticam Mathematicae Pertinentia 16(2024)

ISSN 2080-9751
DOI 10.24917/20809751.16.9

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Modelling the Real World: A Didactic Proposal for an Interdisciplinary Mathematical Modelling Course*

Abstract. This paper presents a comprehensive didactical proposition for an interdisciplinary mathematical modelling course designed for first-semester undergraduate students. The aim is to provide detailed curriculum design, teaching materials, and implementation guidelines directly adaptable by other universities. The course framework integrates Problem-Based Learning methodology with mathematical modelling across six disciplinary modules: operations research, macroeconomics, microeconomics, sociology, epidemiology, and complexity sciences. This proposition includes a structured 17-week curriculum with specific learning objectives, detailed problem scenarios, and assessment rubrics. Each module contains concrete examples, such as transportation network optimisation, economic growth modelling using the Solow model, social network analysis, SIR disease spread models, and chaos theory applications through the Lorenz attractor. The proposition emphasises developing critical thinking, problem-solving, and interdisciplinary collaboration skills through real-world mathematical applications. The course design implements a student-centered approach where instructors serve as learning facilitators, supporting autonomous project development while fostering analytical and technological capabilities required for contemporary workplace demands. Complete evaluation criteria, implementation guidelines, and transferable pedagogical materials enable adoption across diverse institutional contexts.

1. Introduction

Contextualisation

In the modern globalised and technologically advanced society, higher education and professional success depend on the ability to grasp and address complex

*2020 Mathematics Subject Classification: *97M10, 97D40*

Keywords and phrases: *mathematical modelling, interdisciplinary education, problem-based learning, curriculum design, undergraduate mathematics*

problems. This requires a structured approach that connects mathematical theory with real-world applications.

Mathematical modelling, understood as a structured approach to analysing and solving real-world problems using mathematical tools (Hirst, 2025, p. 1), has become an indispensable tool in our complex environment. Murphy (2017, p. 78) highlights that mathematics education should focus on deep learning and the application of mathematics to real-life contexts to prepare students for workplace demands. In this context, deep learning means that "learners can critically learn new ideas and facts, integrate them into the original cognitive structure, connect among many ideas, [and] transfer existing knowledge to new situations" (Liu, 2022, p. 855). Through modelling, students develop three fundamental capacities: critical thinking, problem-solving, and adaptability-skills that form the foundation for success in the 21st century.

Effective mathematical modelling is enhanced by authentic contexts that challenge students to apply theoretical knowledge. As Asempapa (2015, p. 25) states, "model eliciting activities involve tasks of high cognitive demand and twenty-first century learning skills", which encourage students to think beyond traditional approaches and foster creativity and innovation. Through conceptual anchoring, these real-world problems effectively bridge the gap between abstract mathematical concepts and their practical applications.

The complexity of modern challenges rarely fits within a single discipline. By incorporating problems from economics, sociology, epidemiology, and other fields, students develop the ability to apply mathematical modelling across diverse domains, contributing to the interdisciplinary competence that Hazrat et al. (2023) identify as essential for "future workforce requirements" (p. 1). This exposure to problems from various fields enables students to recognise how mathematical structures can represent phenomena across disciplines, preparing them to approach complex problems from multiple perspectives.

The interdisciplinary nature of this approach calls for collaboration among professors from different disciplines, creating a richer learning environment that ensures students receive expert guidance across various fields. To maximise the benefits of this collaborative teaching model, an appropriate pedagogical methodology must be implemented that aligns with both the interdisciplinary nature of the content and the diverse expertise of the instructors.

The *Problem-Based Learning* (PBL) approach provides an ideal framework for mathematical modelling education, as it frequently engages university students in collaboratively addressing complex, real-world problems. As Zakrajsek and Nilson (2023) note, in PBL, "team members review the problem, which is typically ill structured, and clarify the meaning of terms they do not understand" (p. 221). Students then analyse and define the problem, identify what knowledge they possess, and what they need to learn, divide tasks among themselves, conduct individual research, and reconvene to share findings and develop a solution together. This methodology supports the development of what Poláková et al. (2023) describe as essential "21st-century workplace skills, namely critical thinking, problem-solving, communication, collaboration, creativity, and innovation" (p. 6). Beyond mathematical skills, this approach cultivates communication abilities, teamwork, and analytical thinking. These competencies are increasingly valued in professional contexts where success requires "creativity, perseverance, and problem-solving, combined with performing well as part of a team" (p. 6). The ultimate consequences of this approach include both enhanced interdisciplinary cooperation at the institutional level and a fundamental transformation in the role of university instructors, who become facilitators rather than mere transmitters of information. In this transformed educational environment, university instructors should guide students to develop precisely the technological and analytical capabilities demanded by contemporary workplaces. The ability to efficiently apply modern technologies, analyse data, and integrate subject matter expertise becomes essential for "sustainable, fast, efficient, and resilient decision making" (Hazrat et al., 2023, p. 20).

Thus, an interdisciplinary course focused on mathematical modelling would not only enhance technical skills but also cultivate the critical thinking, problem-solving abilities, and adaptability essential for navigating the complex and dynamic demands of the modern workplace, while fostering the collaborative and interdisciplinary mindset necessary for addressing real-world challenges.

Justification for the proposed course

The necessity for an interdisciplinary course in mathematical modelling stems from the increasing demand for professionals capable of addressing complex problems from various viewpoints. Such a course could be especially helpful in the first semesters of college when students are exploring their interests and defining their academic paths. Emphasising theory, the conventional method of teaching mathematics often covers a wide range of topics superficially, without allowing students sufficient time to develop a proper understanding or to see the connections between concepts. This approach reflects what Højgaard (2024) identifies as "syllabusism", defined as a "conviction that results in mastery of a subject being equated with proficiency in a specific subject matter" (p. 461). As Schmidt et al. observe, this leads to "unfocused curricula and textbooks that fail to define clearly what is intended to be taught. They influence teachers to implement diffuse learning goals in their classrooms. They emphasise familiarity with many topics rather than concentrated attention to a few" (Schmidt et al., 1997, as cited in Højgaard, 2024, p. 462). Højgaard further explains that "if an educational system is inclined to equate the mastering of a subject with proficiency in a certain subject matter, then it is very tempting to measure the level of ambition by the amount of subject matter to be covered" (2024, p. 462). This lack of coherence and depth can contribute to a loss of student interest and engagement. This course aims to offset that lack by providing students with a learning environment combining mathematics with several disciplines.

As Kindelan (2022) argues:

> While interdisciplinary integrative learning approaches are not a panacea, they present worthy models. These modes of education offer students valuable ways to develop marketable, sustainable skills; through them, students discover how learning occurs through studying, experiencing, interpreting, evaluating, and synthesizing multiple ways of knowing

and come to understand the importance of learning as a long-term pursuit. (p. 37)

Kindelan (2022) highlights that interdisciplinary integrative learning fosters sustainable skills by encouraging students to study, interpret, and synthesize multiple ways of knowing. This perspective supports the need for a mathematical modelling course that actively engages students in interdisciplinary projects, allowing them to connect knowledge across disciplines. While Kindelan emphasises the value of integrative learning, our proposed course extends this idea by incorporating mathematical modelling as a tool for problem-solving in real-world contexts.

General Course Objective

The course aims to introduce university students to mathematical modelling, understood as a structured approach to analysing and solving real-world problems using mathematical tools. It also aims to promote intellectual curiosity, critical thinking, and exploration of different areas of knowledge, enabling students to apply mathematical models effectively in various disciplines. A more detailed discussion on mathematical modelling and its theoretical foundations is presented later in this in the remainder.

Specific Course Objectives

a) Enhance students' critical thinking and problem-solving skills by engaging them in real-world mathematical modelling tasks that require them to formulate hypotheses, analyse data, and validate their conclusions.

b) To familiarise students with basic concepts of different disciplines and their relationship with mathematics.

c) Stimulate interest in interdisciplinary research and the generation of new knowledge. Facilitate vocational decision making through exposure to various applications of modelling in different fields of study.

d) Develop the ability to apply mathematical models to real-world decision-making processes, considering relevant variables.

2. Theoretical Framework

Mathematical Modelling: Key concepts and their relevance in education.

Throughout this work, we adopt the definition provided by Hirst (2022), who describes mathematical modelling as the "activity involved in finding a solution to a real-life problem by working with a mathematical structure that captures the important characteristics of the situation" (p. 1). The author adds that mathematical modelling has become a crucial tool in various fields, leading to new subdisciplines, and it is used in primary and secondary schools to help students visualise, solve problems, and make connections. A complementary process-oriented view is presented by Baran-Bulut and Yüksel (2024) citing Berry and Houston (1995), who define it as the "process of mathematically expressing a real-life situation that poses a problem and explaining it using mathematical models" (p. 119).

Mathematical modelling connects and fosters the development of various 21st-century skills. It requires deep learning, as students must understand fundamental structures and relationships. The process inherently develops critical thinking because students must evaluate which variables and relationships are significant in each situation. Problem-solving is central to modelling, as the entire process represents a structured approach to addressing real-world challenges. Additionally, developing effective models requires creativity and innovation in simplifying complex systems into manageable representations. As these skills are developed through mathematical modelling, they become mutually reinforcing, enhancing each other in a way that prepares students for complex problem-solving in diverse contexts.

The real-world focus of modelling necessitates multi-disciplinary learning, with students integrating knowledge from multiple fields to create comprehensive solutions. Contemporary modelling practices utilise computational tools and data analysis techniques, further preparing students for modern professional environments. Through the modelling process, students develop analytical and decision-making capabilities as they learn to translate complex real-world problems into mathematical frameworks that provide actionable insights. Ultimately, most models serve to inform better decisions, developing this crucial decision-making skill in students.

The interconnected aspects of mathematical modelling, including critical thinking, problem-solving, and adaptability, work together to enhance students' ability to address complex challenges. By developing proficiency in mathematical modelling, students cultivate these essential skills, which are crucial for success in diverse academic and professional contexts.

Regarding the characteristics of mathematical modelling, an important aspect to remember is that "when using mathematics to solve real world problems one of our aims is to obtain a mathematical model that will describe or represent some aspect of the real situation" (Berry & Houston, 2004).

That is, we do not require to represent the problem in its entirety, only the most relevant aspects of it, in such a way that we will be able to analyse the most important aspects of the real-world problem, without having to analyse every single small detail. The step of simplifying a complex problem into a simpler model is crucial for students, as it helps them not only express complex situations through mathematical models and structures but also develop the ability to identify the most relevant aspects of a real-world situation that should be analysed.

Problem Based Learning (PBL)

As the students are expected to model only the more relevant aspects of each situation presented, this would make it feasible to analyse a different case in each session. Considering this, the proposed course in interdisciplinary mathematical modelling could lend well to be taught using a PBL methodology. As Wood (2003) explains "in PBL students use "triggers" from the problem case or scenario to define their own learning objectives. Subsequently, they do independent, selfdirected study before returning to the group to discuss and refine their acquired knowledge" (p. 328). In our proposed course, we would require that students work individually and in groups, following the PBL methodology, but the most important aspect to remember, is that we do not really expect that students solve world problems in the limited class time, even when they could get good ideas to solve specific problems from their modelling work, but to improve their way of analysing different situations. Wood (2003) goes even beyond that, mentioning that "PBL is not about problem solving per se, but rather it uses appropriate problems to increase knowledge and understanding" (p. 328). This distinction is important for our proposed course, as the focus is not solely on finding solutions to real-world problems but on developing students' ability to analyse situations critically and build conceptual understanding through modelling.

Interdisciplinarity: The importance of connecting different areas of knowledge

The need to promote an interdisciplinary view comes from the fact that the "historically successful functional differentiation within the science system seems to reveal limitations, since the boundaries of the disciplines turned out to restrict scientific development" (Schmidt, 2008, p. 58). The need for an interdisciplinary perspective stems from the fact that current problems rarely fit within the confines of a single discipline, necessitating an integrated approach that combines knowledge from various areas to generate more complete and effective solutions. As a result, designing and implementing an interdisciplinary course entails not only overcoming the constraints of specialisation, but also cultivating an open and collaborative mindset among students, equipping them with the tools to tackle complex issues from multiple perspectives.

The Role of Instructors in Interdisciplinary Teaching

The success of an interdisciplinary course largely depends on instructors' ability and willingness to adopt new methodologies. As Jensen et al. (2019) emphasise, instructors leading such courses must be capable and open to innovative approaches. Additionally, they must be willing to embrace uncertainty in learning, as interdisciplinary courses often deal with problems that do not have a single correct answer. As the authors note, instructors should demonstrate curiosity about emerging theories and research methods, fostering a flexible and participatory learning environment (p. 17). This adaptability is crucial for assessing student work in a setting where learning is centered on knowledge integration and the application of mathematical models to real-world problems. Therefore, training programmes for instructors should include strategies to effectively teach interdisciplinary courses and foster critical thinking among students.

Developing Critical Thinking: How modelling fosters critical thinking and problem solving

Given that mathematical modelling requires students to analyse complex situations, it is reasonable to hypothesise that our proposed interdisciplinary course could foster the development of critical thinking and problem-solving skills. As discussed in the introduction, both higher education and professional success depend on the ability to grasp and address complex problems, which requires students to develop critical thinking and problem-solving skills (Asempapa, 2015, p. 78; Murphy, 2017, p. 18). In fact, “studies have shown that mathematical modelling presents an alternative approach adequate for solving real-life scenarios that promotes and enhances critical thinking” (Asempapa, 2015, p. 18). Furthermore, research indicates that solving complex problems requires knowledge acquisition and application, which involve strategies, such as hypothesis testing, deductive reasoning, and causal analysis (Greiff et al., 2015, p. 20). These cognitive strategies are essential components of critical thinking, as they enable individuals to systematically evaluate information, assess relationships between variables, and make reasoned decisions based on evidence. This connection is further supported by studies that examine the role of mathematical modelling in enhancing critical thinking skills. For example, Acebo (2021) tested this hypothesis in the setting of mathematical modelling for engineers in Mexico, obtaining positive results measured by results in the Cornell Critical Thinking Tests. However, the sample was small, and there was no follow-up, so it remains to be seen if the gains in critical thinking are temporary or permanent. Recent empirical evidence from elementary education in Ecuador indicates that a didactic strategy based on mathematical modelling, structured in sequential phases and emphasising active participation and contextualised activities, contributed to improvements in students’ learning of mathematical problem-solving, and fostered critical thinking and autonomy (Malusín Carabajo et al., 2025, p. 584). While these results were obtained at the primary level, they suggest that the hypothesis underlying our proposed university-level course-that mathematical modelling can foster critical thinking and problem-solving skills-may also hold merit in higher education contexts.

3. Course Design

The course commences with an examination of fundamental modelling concepts and progressively tackles more intricate and multidisciplinary challenges. This sequence enables students to cultivate a robust comprehension of modelling fundamentals and apply them to practical scenarios.

Operations Research: We present operations research, a “branch of mathematics-specially applied mathematics, used to provide a scientific base for management to take timely and effective decisions to their problems” (Murthy, 2005, p. 2), as it offers essential tools for the development and evaluation of mathematical models. Students acquire the skills to formulate and resolve optimisation problems derived from real-world situations, crucial in various domains, including logistics and finance.

Macroeconomics: The course subsequently explores macroeconomics, utilising Operations Research principles to address extensive economic issues. Students examine models that elucidate the behaviour of entire economies and evaluate economic policies.

Microeconomics: After the macroeconomic analysis, we shall concentrate on individual economic agents. Students employ mathematical models to examine consumer and firm behavior and analyse markets.

Sociology: We broaden our analysis to encompass social phenomena, modelling the interactions between individuals and groups. Students investigate social networks, population dynamics, and various intricate social processes.

Epidemiology: The course subsequently employs mathematical models to analyse the dissemination of infectious diseases. Students develop mathematical models to analyse the spread of infectious diseases, focusing on the modelling process rather than a deep understanding of epidemiology itself.

Complexity Sciences: Ultimately, we examine complex systems, defined by numerous components interacting nonlinearly. While this topic is more advanced than others in the course, it will be introduced at an appropriate level through PBL, allowing students to explore how complexity concepts apply to their own project choices. Students examine phenomena including chaos, self-organization, and emergence, pertinent across multiple disciplines.

Course Structure

This course is structured to ensure that students gradually acquire the tools and concepts required to address problems that become more intricate. We start by going over the basics of mathematical modelling and then look at how it can be used in different areas. Students work on their own projects at the end of the process, where they can use what they have learned in creative ways.

During the first three weeks, classes will follow a foundational lecture format, providing students with clear and structured presentations of essential concepts and terminology in mathematical modelling. In week four, students will participate in a hands-on computational lab, gaining practical experience with modelling software and programming tools.

From week five onward, each thematic module will begin with a brief interactive lecture introducing the key concepts and mathematical tools relevant to the field under study. Most of the class time will then be devoted to problem-based learning activities, where students collaboratively analyse real-world scenarios and develop mathematical models. This approach ensures that theoretical knowledge is immediately applied and reinforced through authentic, interdisciplinary problems.

Weeks 1–4: Theory and Tools

Objective: Introduce students to fundamental concepts of mathematical modelling, including its definition, processes, types, and computational tools, ensuring they acquire the necessary foundation for applying modelling techniques in later weeks.

Week 1: Introduction to Mathematical Modelling Concept of mathematical model.
Week 2: Phases of the modelling process.
Week 3: Types of mathematical models (deterministic, stochastic, discrete, continuous).
Week 4: Computational tools for modelling (software, programming languages).

Weeks 5–15: Thematic Modules

Week 5–6: Operations Research (linear programming, graph theory).

Objective: Equip students with tools to formulate and solve optimisation problems, applicable in logistics and supply chain management.
Example: Analysing transportation networks to minimise delivery costs.
Week 7–8: Macroeconomics (economic growth models, economic cycles).
Objective: Equip students with the ability to analyse macroeconomic phenomena using mathematical models, focusing on economic growth and cyclical fluctuations.
Example: Modelling the Solow growth model to understand the determinants of long-run economic growth and the role of technology.
Week 9–10: Microeconomics (consumer theory, production theory).
Objective: Provide students with the tools to analyse individual economic agents' behaviour and the functioning of markets using mathematical models.
Example: Modelling consumer choice using utility functions and indifference curves to understand how consumers allocate their income.
Week 11–12: Sociology (social network models, population dynamics).
Objective: Introduce students to the use of mathematical models in sociology to analyse social networks and population dynamics.
Example: Modelling the spread of information or opinions through social networks using graph theory.
Week 13–14: Epidemiology (Models of disease spread).
Objective: Equip students with the ability to analyse the spread of infectious diseases using mathematical models, including compartmental models and network models.
Example: Modelling the SIR (Susceptible-Infectious-Recovered) model to understand the dynamics of disease outbreaks and the effectiveness of public health interventions.
Week 15: Complexity Sciences (dynamical systems, chaos theory).
Objective: Introduce students to the concepts of dynamical systems and chaos theory, and their applications in various fields.
Example: Modelling the Lorenz attractor to understand the concept of deterministic chaos and its implications in complex systems.

Week 16–17: Final Project: Autonomous Project.
Students select a topic of their own interest and develop a modelling project, presenting their results at the end of the course. Students would then research the topic, collect relevant data, develop a mathematical model, analyse the results, and present their findings in a written report and oral presentation.
Objective: Provide students with the opportunity to apply their knowledge and skills in mathematical modelling to a real-world problem of their choice, fostering creativity, independent research, and problem-solving abilities.
Example: Students could choose a topic related to their interests or future career goals, such as modelling the impact of a new government policy on economic growth, modelling the spread of pollution in a river system, modelling the population dynamics of a species in a particular ecosystem, etc.

Teaching and Learning Strategies

The course utilises diverse pedagogical methods to enhance effective learning. Lectures present theoretical concepts and mathematical tools, whereas practical problem-solving exercises enhance comprehension and application. To promote collaboration and teamwork, students participate in group projects and discussions. Personal projects facilitate the enhancement of research and presentation competencies. Moreover, students acquire practical experience with computational tools for modelling, thereby improving their capacity to apply mathematical concepts to real-world issues.

Evaluation

Class participation:

Students are evaluated based on the following criteria:

Resolution of tasks and exercises: Accuracy, completeness, and clarity of mathematical reasoning in problem-solving activities.

Teamwork: Contribution to group discussions, collaboration in exercises, and engagement in peer activities.

Final project: Autonomous project:

Examples of possible final projects include modelling the optimisation of delivery routes to minimise costs in a logistics company (based on the Operations Research module); analysing the impact of a new government policy on national economic growth using the Solow model (based on the Macroeconomics module); modelling consumer choice and demand for a new product using utility functions (based on the Microeconomics module); simulating the spread of opinions or behaviors through a social network (based on the Sociology module); modelling the outbreak and control of an infectious disease in a community using the SIR model (based on the Epidemiology module); and analysing chaotic dynamics in financial markets during panic or crisis, such as sudden stock market crashes or extreme volatility events (based on the Complexity Sciences module). Students are encouraged to select a real-world problem of personal or professional interest, drawing on the concepts and modelling techniques discussed in any of the course modules.

The following criteria are considered for evaluating autonomous projects:

- Originality of the topic: the choice of a relevant and novel topic within the field of mathematical modelling.
- Quality of the mathematical model: the relevance of the selected model, its complexity and capacity to represent the studied phenomenon.
- Clarity of presentation: the organisation, coherence and clarity of the written and oral presentation of the project.
- Ability to defend the conclusions: the student's ability to justify the results obtained and answer questions about their work.

To ensure a fair and transparent evaluation, a detailed rubric has been developed and can be found in the annex. This rubric will allow an objective evaluation of each of the mentioned criteria.

Additional Considerations

In order to ensure meaningful learning adapted to the individual needs of each student, especially considering that these are first-semester students, the course will be characterised by its flexibility, allowing the contents and depth of the topics to be adapted according to the participants' level and interests. Moreover, interdisciplinarity will be encouraged through the invitation of professors from different areas, thus enriching the learning experience.

The use of a variety of didactic resources, such as books, scientific articles, videos and software, will provide students with multiple perspectives and tools to address the problems posed. For example, students may consult Mathematical Modelling by Berry & Houston (2004) for foundational concepts; read accessible case studies from the UMAP Journal, such as the 45.4 Winter 2024 Edition (Campbell, 2024), which features real-world modelling problems from the Mathematical Contest in Modelling published by COMAP (The Consortium for Mathematics and its Applications); watch "Lecture 1: Basics of Mathematical Modelling" (DrMaths, 2020) for an introduction to modelling concepts; follow the Math Modelling video series by Jason Bramburger (2023), which covers core modelling techniques such as the five-step modelling process, optimisation, dynamical systems, and probability models; or analyse the video "Chaos theory and geometry: can they predict our world?" presented by Tim Palmer (The Royal Institution, 2023) to understand chaos and complexity in real-world contexts.

Additionally, students will engage with activity-based modules developed by COMAP, such as Modelling Botpaths with Linear Functions (Davis & Froelich, 2022), where they use linear functions and coordinate geometry to determine optimal paths for robots navigating around obstacles-an activity that integrates mathematical reasoning, technology (e.g., graphing calculators or GeoGebra), and real-world problem-solving.

In terms of software, students will gain practical experience with tools like Excel for data handling, Python for basic simulations and modelling, GeoGebra for interactive visualisation, and NetLogo for agent-based modelling. These resources are selected to ensure accessibility and relevance for first-year students, supporting individual exploration and collaborative, interdisciplinary projects.

Furthermore, the course design explicitly highlights the instructor's role as a facilitator of learning rather than a mere transmitter of information. In a PBL environment, the instructor guides students in formulating and refining real-world problems, selecting appropriate modelling tools, and connecting ideas across multiple disciplines. This includes providing support through "scaffolding" strategies in the early stages so that students can gradually build autonomy and confidence in their modelling abilities. As they progress, the instructor reduces direct guidance, encouraging students to explore, hypothesise, and validate their models more independently. By actively modelling interdisciplinary thinking, the instructor sparks curiosity, fosters critical reflection, and demonstrates the relevance of mathematical modelling for addressing complex challenges.

Building on the PBL approach, the course emphasises process-oriented learning. The main objective is to translate real-life problems into mathematical models, rather than to arrive at a single numeric solution. For instance, two teams analysing the same real-life problem might produce very different numerical results, depending on how realistic the assumptions are within their respective models.

Finally, students will receive continuous feedback through formative assessments, which will help the instructor and the students themselves identify any areas needing additional explanation or alternative approaches. This ongoing dialogue ensures that the content is not only delivered but also understood and integrated by the learners. Group work and collaborative discussions will further promote the exchange of ideas, effective communication, and the ability to integrate multiple perspectives-essential skills in any interdisciplinary context.

4. Potential Benefits

An interdisciplinary mathematical modelling course should provide numerous benefits to both students and the institution. Skills like critical thinking, effective communication, teamwork, solving complex problems, and the ability to justify their findings in oral presentations, are highly appreciated in today's job market, and this course aims to help students develop them. The course will help students improve their understanding of mathematical concepts and equip them with skills to make informed career decisions by relating mathematics to real-world problems and diverse disciplines. Furthermore, it will foster intellectual curiosity and encourage students to seek innovative solutions to complex problems.

From an institutional perspective, this course can enrich academic offerings, foster interdisciplinary collaboration, and demonstrate commitment to innovative pedagogy. While it may enhance the institution's reputation for educational innovation, success depends on consistent faculty engagement, adequate resources, and careful curricular design. Finally, by equipping students with the skills needed to navigate the increasingly complex demands of the 21st century, the course supports the institution's broader mission of preparing graduates to excel in this era.

5. Limitations and Future Research

In this section, we discuss the potential limitations associated with the implementation of the proposed interdisciplinary course and outline possible avenues for future research to refine the course design and maximise long-term impact on students' academic and professional development.

Potential difficulties in implementation

A common challenge in implementing interdisciplinary courses is the need for teachers with strong backgrounds in mathematics and other disciplines. However, this difficulty can be addressed through collaboration among faculty from different departments and the use of online resources. Given that the course is intended for all first-year students across multiple curricula, we propose that the final responsibility for designing and updating its content be assigned to an institutional-level committee or board. This approach ensures alignment with the university's overarching academic standards and fosters cohesive planning among various departments.

Regarding technological resources, the availability of specialised software can present a constraint. Meanwhile, many colleges have licenses for statistical tools including SPSS or Stata, and there are free substitutes, including R and Python, that provide sophisticated modelling capability.

Another challenge that may arise is the heterogeneity of students in terms of prior knowledge. To address this issue, it is proposed to offer complementary materials and leveling activities. Moreover, the evaluation of an interdisciplinary course can be complex, so it is suggested to use a combination of evaluation methods and develop clear rubrics.

The implementation of such a course can significantly increase workload not only for students but also for instructors, especially if they are concurrently teaching other subjects or have additional responsibilities. To mitigate this, institutions should provide structured support, such as targeted training sessions, allocated time for collaboration, and recognition of cross-disciplinary teaching efforts.

For students, it is suggested to design activities that promote autonomous and collaborative learning – such as group projects and online discussion forums – and to maximise class time for practical tasks, including programming assignments or spreadsheet computations. Recognising the variety of learning rhythms, extra seminars and tutorials will be offered outside of scheduled classes, giving students individualised help and the chance to delve deeper into topics they find challenging.

Future research

The limitations identified in this proposition open several lines of future research. Among them is the need to develop the design of evaluation instruments that allow a more precise measurement of the development of transversal skills, such as critical thinking, complex problem-solving, and creativity in students taking interdisciplinary subjects. Examining how these disciplines affect students' academic performance and motivation, as well as their capacity for efficient peer collaboration across several fields is also pertinent. Furthermore, exploring how instructors adapt to and manage their evolving roles, from traditional lecturers to facilitators of cross-disciplinary thinking, can shed light on faculty workload, job satisfaction, and the pedagogical support required for long-term institutional success. More efficient collaboration models should be investigated in future studies and their effects on the quality of education, as well as the creation of cooperative networks spanning the academic career of the students.

6. Conclusions

By focusing on real-world scenarios and guiding students to construct and analyse mathematical models, a first-semester interdisciplinary modelling course establishes a clear progression of educational benefits. The course begins by providing students with a robust understanding of mathematical modelling as a powerful approach to problem-solving that connects abstract concepts with practical applications. Through exposure to authentic contexts from various disciplines, students develop the ability to identify relevant variables and relationships in complex situations, a fundamental aspect of mathematical modelling that enhances critical thinking.

The interdisciplinary nature of the presented problems requires collaboration among professors from different fields, creating a rich learning environment where students can benefit from diverse expert perspectives. This collaborative teaching model is proposed to be implemented through PBL methodology, which aims to engage students in solving complex, real-world problems through collaborative investigation. Beyond technical skills, this approach is designed to cultivate essential communication abilities, teamwork, and analytical thinking, which are competencies increasingly valued in professional contexts.

This educational approach offers two significant benefits. First, it contributes to interdisciplinary collaboration within the departments involved, fostering academic connections that can enrich both teaching and learning. Second, it applies a student-centered pedagogical model where instructors act as facilitators of learning rather than mere transmitters of knowledge, an approach widely recognised in contemporary education. In this learning context, instructors support students in developing technological and analytical capabilities relevant to current workplace environments, where the ability to apply modern technologies, analyse data, and integrate expert knowledge proves valuable for effective decision-making.

Through this comprehensive approach, the course nurtures three core capacities that form the foundation of successful mathematical modelling: critical thinking (analysing problems and selecting relevant variables), problem-solving (developing and refining mathematical representations), and adaptability (modifying approaches based on feedback and changing conditions). By developing proficiency in these interconnected capacities, students are prepared not only for academic success but also for meaningful engagement with the complex challenges of the 21st-century workplace and pressing global issues.

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Annex

Rubric for the Final Project (Autonomous Project)

Criterion \Performance Level	Meets Expected Standard (25 pts)	Approaching Standard 2 (20 pts)	Approaching Standard 1 (15 pts)	Initial (10 pts)	Does Not Meet (0 pts)
1. Originality of the Topic	The selected topic is novel and relevant to the field of mathematical modelling, with a clear potential to contribute to the understanding or solution of a real-world problem.	The topic shows some novelty and relevance, though its real contribution could be clarified or expanded.	The topic is moderately interesting but lacks significant innovation or remains too broad, offering only limited potential for problem-solving or deeper insight.	The topic has minimal relevance or originality, and its importance in the context of mathematical modelling is unclear.	The topic shows no originality or relevance to modelling; it fails to meet the minimum established requirements.
2. Quality of the Mathematical Model	The model is coherent, well-structured, and effectively represents key aspects of the phenomenon. The choice of assumptions and variables is clearly justified.	The model is generally functional and coherent, but requires greater precision in certain assumptions or variables to accurately represent the phenomenon.	The model shows partial inconsistencies or lacks sufficient justification of assumptions. Not all central aspects of the phenomenon are well captured.	The model is incomplete or poorly structured; assumptions and variables lack solid justification, making the phenomenon's representation unclear.	No viable mathematical model is presented, or it completely lacks justification and coherence.
3. Clarity of Presentation (Written and Oral)	Both written and oral presentations are clear, logical, and well-organized. Visual aids are used appropriately, and the methodology is explained in a way that is accessible to the audience.	The presentation is mostly clear and organized, but could improve in sequencing or oral delivery to maintain coherence and audience engagement.	The written or oral components have issues with coherence or sequencing; visual aids are used sparingly, or the methodology is insufficiently explained.	The presentation lacks fluency and organization; the audience struggles to follow the logic or understand the methodology employed.	No coherent document or oral presentation is provided; the content is not communicated in an understandable manner.
4. Ability to Defend Conclusions	Each result is justified with solid arguments, appropriate data, and critical analysis. The student responds confidently and convincingly to questions or critiques.	Reasonable arguments and sufficient data are presented; the student answers most questions adequately, though some depth or clarity may be lacking.	The results are partially explained; the student experiences difficulty defending assumptions or answering questions. The conclusions lack consistency.	The arguments are weak or poorly substantiated. Gaps appear in explaining the results, and the student does not defend their claims clearly.	No defense of conclusions is provided or the claims lack support; the student does not respond to questions or the responses are not relevant.

In this layout, each criterion is equally weighted at 25 points. However, the distribution of points may be adjusted to align with specific institutional priorities and any agreements set forth by the institutional-level committee or board in charge of the course. This flexibility ensures that the rubric reflects the university's overarching academic standards and the diverse needs of first-year students across various curricula.

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