# Indian Institute of Science Engineering Students Use MATLAB to Solve Multidisciplinary Problems

*Dr. Pratap with students.*

**The Challenge**

Teach multidisciplinary engineering principles to graduate students from diverse backgrounds

**The Solution**

Use MATLAB across the mechanical engineering curriculum to enable students to solve problems spanning multiple domains

**The Results**

- Student engagement increased
- Multidisciplinary topics quickly mastered
- Students prepared for jobs in multiple industries

The Indian Institute of Science (IISc) is India's premier research institution for science and engineering. The curriculum spans biology, chemistry, physics, environmental sciences, and numerous engineering disciplines.

The study of microelectromechanical systems (MEMS) within the Department of Mechanical Engineering reflects this diversity of disciplines. MEMS devices integrate electrical and mechanical functionality and are less than 100 micrometers across. Engineering a MEMS device requires knowledge of electrostatics, mechanics, fluid dynamics, acoustics, and other fields.

IISc faculty have integrated MATLAB® in MEMS coursework and throughout the mechanical engineering curriculum. "Our students must calculate electrical forces, apply them on mechanical structures, model mechanical deformations, determine how the deformation affects the electrical field, and visualize the entire solution," explains Dr. Rudra Pratap, professor, Department of Mechanical Engineering. "MATLAB enables them to do all this in a single environment, which makes the entire MEMS development process much easier to teach and to learn. The shared environment also fosters student-teacher collaboration."

## The Challenge

MEMS courses attract graduate students from diverse backgrounds, making it difficult for professors to find computational tools that all can use. Mechanical engineering students, for example, are typically familiar with finite element method (FEM) tools, whereas electrical engineering students can be intimidated by them.

Dr. Pratap and his colleagues needed computational tools that students from a variety of fields could quickly apply to multidisciplinary engineering problems. "Our biggest challenge is pulling together concepts from many areas and teaching them to students from varied backgrounds," says Dr. Pratap. "We need tools that our students can apply rapidly, to learn concepts from the ground up."

## The Solution

Dr. Pratap integrated MATLAB into his MEMS courses at IISc.

In Introduction to MEMS, Dr. Pratap shows students how to implement FEM analysis in MATLAB. Unlike commercial FEM tools, MATLAB gives students access to the algorithms, which gives them a much better understanding of what is happening. Starting with basic programming constructs, the students generate stiffness and mass matrices, assemble them into global matrices, apply boundary conditions, and conduct convergence studies.

Later, they combine their FEM models with electrostatics and electrodynamics models in MATLAB to simulate MEMS devices. The students also use MATLAB to analyze the dynamics of coupled structures by solving the resulting eigenvalue problems.

MATLAB also plays a central role in two other graduate-level courses taught by Dr. Pratap.

In Dynamics and Control of Mechanical Systems, Dr. Pratap uses MATLAB to take a new approach to teaching classical mechanics. Traditionally, the elliptical orbits that describe planetary motion are derived over

*"In three lectures, I can have students implement a complete FEM solution for beam deflection and plate deflection in MATLAB. I don't know of any other programming language or platform that we could use to do this." —Dr. Rudra Pratap, IISc*

several lectures using Newton's laws and nonlinear differential equations.

Using MATLAB, Dr. Pratap demonstrates a computational solution to the complex differential equations, enabling the students to move from the fundamental laws to visualizing the mechanics of planetary motion in a single lecture.

Students use MATLAB to complete all assignments, which typically include solving nonlinear differential equations.

In Modeling and Simulation of Dynamic Systems, students use MATLAB to explore more complex dynamic systems in the mechanical domain, as well as population and disease dynamics. They solve systems of ordinary differential equations and evaluate various algorithms for stability and accuracy.

Students also learn how to use MATLAB to perform fast Fourier transforms (FFTs) for frequency domain analysis. "Many electrical engineering students are familiar with FFTs, and most mechanical engineering students are not, but they all gain a deeper understanding from seeing how FFTs are implemented from scratch in MATLAB," explains Dr. Pratap.

For students in IISc's newly established undergraduate program, Dr. Pratap is preparing a series of introductory lectures based on his book *Getting Started with MATLAB: A Quick Introduction for Scientists and Engineers*.

## The Results

**Student engagement increased.** "In a matter of weeks the students are not only solving involved technical problems with MATLAB; they are also getting a deeper understanding of the concepts involved. They are more engaged because they can see the entire physical system—for example, a double pendulum—working as expected via animations, which is much more fun than looking at a series of equations," says Dr. Pratap.

**Multidisciplinary topics quickly mastered.** "My students have backgrounds in materials science as well as aerospace, electrical, and mechanical engineering," notes Dr. Pratap. "With MATLAB I can teach them how to solve problems that span multiple domains, because we can start with the basics and rapidly build complete solutions. Essentially, we train T-shaped engineers—engineers with deep understanding of a specialist domain who are also educated broadly in their colleagues' domains."

**Students prepared for jobs in multiple industries.** "Many of my students have received job offers specifically because they had experience with MATLAB. The companies were in automotive, aerospace, and other industries, but they all had projects that required MATLAB skills."

## Industry

- Academia
- Electronics and semiconductors

## Application Areas

- Data analysis
- Mathematical modeling
- Algorithm development
- Mechatronics

## Products Used

- MATLAB®

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