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Pedagogical Methods for Mathematics in engineering for Gen Z, Aligning with NEP 2020

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Abstract

This paper provides reviews of teaching methods which are already in use and emerging in Under graduate engineering programs, by focusing mainly on National Education policy 2020.It gives a detail summary of current practices in class room including traditional lectures, flipped classrooms, blended learning, project Based learning, active learning and digital resources. It evaluates their effectiveness in engineering mathematics and suggests teaching innovations and institutional actions that align with NEP goals, like multidisciplinary learning, foundational skills, assessment reform, and digital inclusion. The recommendations, including adaptive learning, AI tutors, competency-based learning, micro-credentials, faculty development, and partnerships with industry, are provided.

Keywords: Engineering mathematics, NEP 2020, flipped classroom, project-based learning, peer learning, blended learning.

Introduction:

Why NEP Matters? NEP 2020 calls for a major change in India's education system, stressing multidisciplinary learning, foundational skills, experiential and competency-based methods, flexibility in course choices, and a significant role for technology and open educational resources. These principles impact mathematics instruction in engineering directly since mathematics is essential for engineering thinking, problem-solving, and modeling. To achieve NEP's aims, engineering mathematics must shift from rote learning to quality based student-centered, application-focused, and digitally-enabled teaching.

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Review of Literature:

The Flipped Classroom approach significantly enhances student engagement and understanding of complex Engineering Mathematics concepts. By reversing traditional learning dynamics, students engage with theoretical content outside the classroom, allowing for more interactive and collaborative learning during class time. This method has been shown to foster deeper cognitive, emotional, and behavioral engagement among students, particularly in STEM fields. Huang, C.-C., & Weng, F. Y. (2025), their findings are, the experimental group utilizing the flipped classroom model significantly outperformed the control group in post-test academic scores (M=81.47 Vs 74.19, $p<0.001$). Students in the flipped classroom demonstrated improved learning test, autonomy, participation and self-confidence. There was a notable reduction in Mathematics anxiety among students in the flipped classroom. Classroom observations indicated higher engagement levels in the flipped classroom compared to the traditional instruction.

Raj, N., Sharma, E., Singh, N., Downs, N., Salmeron, R., & Galligan, L. (2025) found that the flipped-classroom approach significantly improved first-year engineering students' self-reported confidence, competence, and knowledge development in mathematics, indicating enhanced engagement and understanding of complex concepts, as evidenced by statistical analysis of survey data.

Project-based learning (PjBL) and problem-based learning (PBL) significantly enhance student engagement and motivation in STEM education by fostering active participation and real-world problem-solving skills. Both approaches encourage students to take ownership of their learning, leading to increased intrinsic motivation and interest in STEM careers. Hakim, U., Syamsurianti, S., Zaini, S. H., Bahri, A., & Suardi, S. (2025) their study found that Project-Based Learning (PjBL) significantly enhanced student engagement and character development, while Problem-Based Learning (PBL) led to greater academic achievement. Da Costa, L. A., & Reis, M. J. C. S. (2025), in their paper, Project-based learning and problem-based learning enhance student engagement and motivation in STEM education by fostering authentic problem-solving, promoting collaboration, and providing frequent feedback, leading to greater interest, competence, and persistence.

The review does not address the specific challenges educators face when implementing these active learning methodologies in diverse classroom, long term impact of these techniques which is crucial for understanding practical applications.

Goals for Engineering Mathematics Education Under NEP

(i) Foundational competency ensure every engineering student develops strong conceptual numeracy and problem-solving skills, beyond just procedural fluency [1].

(ii) Multidisciplinarity & flexibility: Provide mathematics modules connected to discipline-specific problems and electives across areas like data science and numerical methods [2].

(iii) Learner-centered & active pedagogy: Implement teaching methods that support active learning, higher-order thinking, and collaboration**.**

(iv) Digital & open resources: Build national and local repositories, multimedia content, and assessment tools to assist a variety of learners **.**

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Current Pedagogical Methods Used in Engineering Mathematics:

Emphasis shifted to analytical learning using problem sets contextualized within engineering applications, enhancing conceptual understanding. Integration of interdisciplinary problems (e.g., applying calculus in fluid dynamics) fostered holistic thinking.

Traditional Lectures with Problem Sessions:

These remain common in many engineering programs. While lectures are effective for content delivery, they often lead to shallow learning and limited transfer to real engineering scenarios. Means minimal practical application and passive learning.

Flipped Classroom:

Students watch videos or read material before class; class time focuses on problem-solving, discussions, and applied activities. Reviews show flipped learning increases engagement and understanding, but issues with student preparedness and workload can arise if not structured well. Evidence from case studies supports careful implementation with support and clear expectations.

Project-Based Learning and Problem-Based Learning:

Incorporating mathematics into projects helps students recognize its relevance, leading to deeper learning and retention. Hands-on projects (Models) linking mathematical theory with real-world engineering challenges. Explain Difficult concepts through animation.

Blended and Online Learning (MOOCs, OER, LMS):

These options gained popularity after the pandemic by offering flexibility. Effectiveness relies on active involvement; simply moving lectures online is not enough.

Active Learning / Peer Instruction / Tutorials:

Active teaching methods, such as think-pair-share, discussions (critical thinking questionnaires, connecting new information to existing knowledge) and peer instruction, consistently improve understanding, one to one interaction in Tutorials and providing feedback.

Computational Labs, Simulation, and Software-Enabled Learning:

Using tools like MATLAB, GeoGebra, Python, and Mathematica to connect theory with computation is a well-established best practice in engineering mathematics.

These methods were evaluated for their alignment with NEP goals of fostering flexible, experiential, interdisciplinary, and inclusive education.

Examples

(I) Course-Level Reports: Several studies document successful flipped classroom pilots and other activity-based learning in first-year and Second year engineering mathematics, noting increased engagement. The following reports mentioned about the process of each activity also provides limitations, mitigation plan and improvement in the student's level of understanding. These reports also help the educator about the activity conduction in detail. Flipped classroom Activity and TBLC

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activity applied for every student. Mathematics Animation project has been given only for advanced learners.

a. Flipped classroom Activity Report

FLIPPED CLASSROOM ACTIVITY REPORT

Course: Calculus and Differential Equations

Unit: Unit 4 (Applications of First-Order ODEs)

Topics Covered: Newton's Law of Cooling, Rate of Growth and Decay

Aligned Course Outcome (CO): CO4 - Analyze real-world phenomenon governed by first-order ordinary differential equations

PO's mapped in this activity: PO1, PO2, PO3, PO4, PO9, PO10

Date of In-Class Activity: 15 November, 2024

Instructor: Sini Ronson

➢ **Introduction:** This report details the implementation and outcomes of a flipped classroom pedagogical strategy for Unit 4 of the Calculus and Differential Equations course. The activity focused on two key topics: **Newton's Law of Cooling and Rate of Growth and Decay**. The primary objective was to enable students to achieve **CO4** by shifting the foundational knowledge acquisition to a self-paced, pre-class activity and utilizing valuable in-class time for collaborative problem-solving and deeper analysis. The strategy involved a pre-recorded video lecture, a pre-survey, an in-class problem-solving session, and a post-survey. Analysis of the surveys indicates a significant improvement in student confidence and a deeper conceptual understanding of applying first-order ODEs to real-world problems.

➢ **Activity Design and Implementation**

The activity was conducted in three distinct phases over a one-week period.

Phase 1: Pre-Class Activity (One Week Prior)

- **Activity:** Pre-recorded video lectures on the two topics were uploaded to the Moodle Learning Management System.
- **Video 1:** Derivation of Newton's Law of Cooling from the general law of heat transfer, solution to the ODE, and one worked-out example.
- **Video 2:** Formulating the general exponential growth/decay equation, solution, and applications in population growth and radioactive decay.
- **Student Task:** Students were given one week to view the videos at their own pace and take notes.
- **Pre-Survey:** A short, ungraded pre-survey of 5 questions was released on Moodle to gauge initial student understanding and confidence.

Phase 2: In-Class Activity

- **Brief Recap (10 mins):** A quick, interactive Q&A session to clarify any fundamental doubts from the videos.
- **Problem-Solving in Groups (30 mins):** Students were divided into small groups (3-4 students each). Each group was given a worksheet with two complex problems:
  1. **Problem 1 (Newton's Law of Cooling):** "A murder victim is discovered at midnight. The body temperature is 85°F. One hour later, the temperature is 80°F. The ambient room temperature is a constant 70°F. Estimate the time of death."
  2. **Problem 2 (Growth/Decay):** "An archaeological artifact has 20% of the original Carbon-14 remaining. Given that the half-life of Carbon-14 is 5730 years, determine the approximate age of the artifact."
- **Instructor's Role:** The instructor circulated among the groups, facilitating discussions, prompting with guiding questions, and addressing specific hurdles.
- **Fruitful Discussion & Consolidation (20 mins):** The class reconvened, and one group presented their solution and reasoning for each problem. This sparked a whole-class discussion on the assumptions made (e.g., constant ambient temperature), the solution process, and the interpretation of results in a real-world context, leading to a much better collective understanding.

Phase 3: Post-Activity Assessment

- **Post-Survey:** An identical 5-question survey was administered at the end of the class session to measure the immediate impact of the activity.

➢ **Challenges Faced:**

- Uneven Student Preparedness
- Student Resistance to the Non-Traditional Model
- Assessing Individual Contribution

➢ **Mitigation Plan:**

- A mandatory, graded quiz on Moodle based directly on the video content to be completed before the in-class session.
- Use data and evidence to show how flipped classroom model improves learning outcomes, particularly for application-based subjects.
- Implement a brief, confidential peer-evaluation, where students can rate their own and their group members' contributions, encouraging accountability.

➢ **Conclusion and Reflections:**

- The flipped classroom activity on Newton's Law of Cooling and Rate of Growth/Decay was successful in attaining its primary goal of allowing students to analyze real-world phenomena (CO4). The model effectively transferred the knowledge-absorption phase outside the classroom, freeing up in-class time for the critical higher-order cognitive tasks of application, analysis, and collaborative problem-solving.
- The significant improvement in survey scores, coupled with the energetic and fruitful discussions observed during the class, strongly supports the continued use of this pedagogical strategy for application-oriented topics in engineering mathematics. Future iterations could include a brief graded quiz based on the video content to ensure a higher degree of student preparedness before the in-class activity.

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b. TBLC Activity Report

TBLC Team-Based Learning™ Collaborative

Class	:	SY BTech
Name of Course	:	Applied Mathematics (AS202)
Name of the Topic	:	Solution of system of equations using Gauss Elimination method
Name of Activity	:	Team based learning

Problem Statement:

Describe Gauss elimination method for solving system of linear equations. Solve the system of linear equations using Gauss elimination method.

Details about the conduction of the activity:

TBL is a collaborative learning teaching strategy.

TBL consists of 3 steps cycle.

1. Individual Pre-work
2. Test: IRAT and TRAT
3. Clarification and application exercises

Actual conduction of the activity:

Step 1: Preparation

Informed the students about activity before one week.

Please follow the link given here for the flipped classroom activity.
https://www.youtube.com/watch?v=2j5Ic2V7wq4

Students watched the video at home.

Step 2: Test

IRAT (Individual Readiness Assurance Test)

At the beginning of class, students completed individual online quiz.

TRAT (Team Readiness Assurance Test)

After submitting IRAT, students formed group and take the same test and submit answers.

Step 3: Clarification and Application exercise

After submitting both IRAT and TRAT, students raised their questions. Course teacher addressed the questions.

Gave challenging assignment to group of students.

Pre-reflection

- ✓ IRAT is effective to check how many students have watched the video.
- ✓ TRAT is effective to check how many students have understood the concept of Gauss Elimination method.
- ✓ Final application-based assignment is to check how many students can apply the knowledge of Gauss Elimination method to solve real world problem.

Challenges/issues

- ☹ Assessment of each Student (For TRAT): We cannot ask each student individually for their views/ Solution.
- ☹ How to evaluate the team work skills?

Strategies to be used to avoid these problems:

- ☺ We can give 5 to 10 minutes to respond on a blank sheet of paper and ask them to put their name on paper. After collecting the papers, they can form group for TRAT.

Outcome

After completing TBL students are attained:

- ✓ An ability to apply the knowledge of Gauss Elimination method to solve any system of equations.
- ✓ An ability to design system of equations as well as to analyze and interpret data
- ✓ An ability to use the techniques and tools necessary for engineering practice.

Mathematics Animation Project (Not established widely):

The Computational Mathematics using Manim (Math Animation) [14] and Python activity aimed to integrate programming with mathematics to enhance visualization, logical thinking, and problem-solving. Students learned Python fundamentals, algorithmic thinking, and game development using PyGame, followed by creating mathematical animations with Manim. Conducted through interactive seminars and weekly projects, the program encouraged teamwork and creativity. Participants gained hands-on experience in coding,

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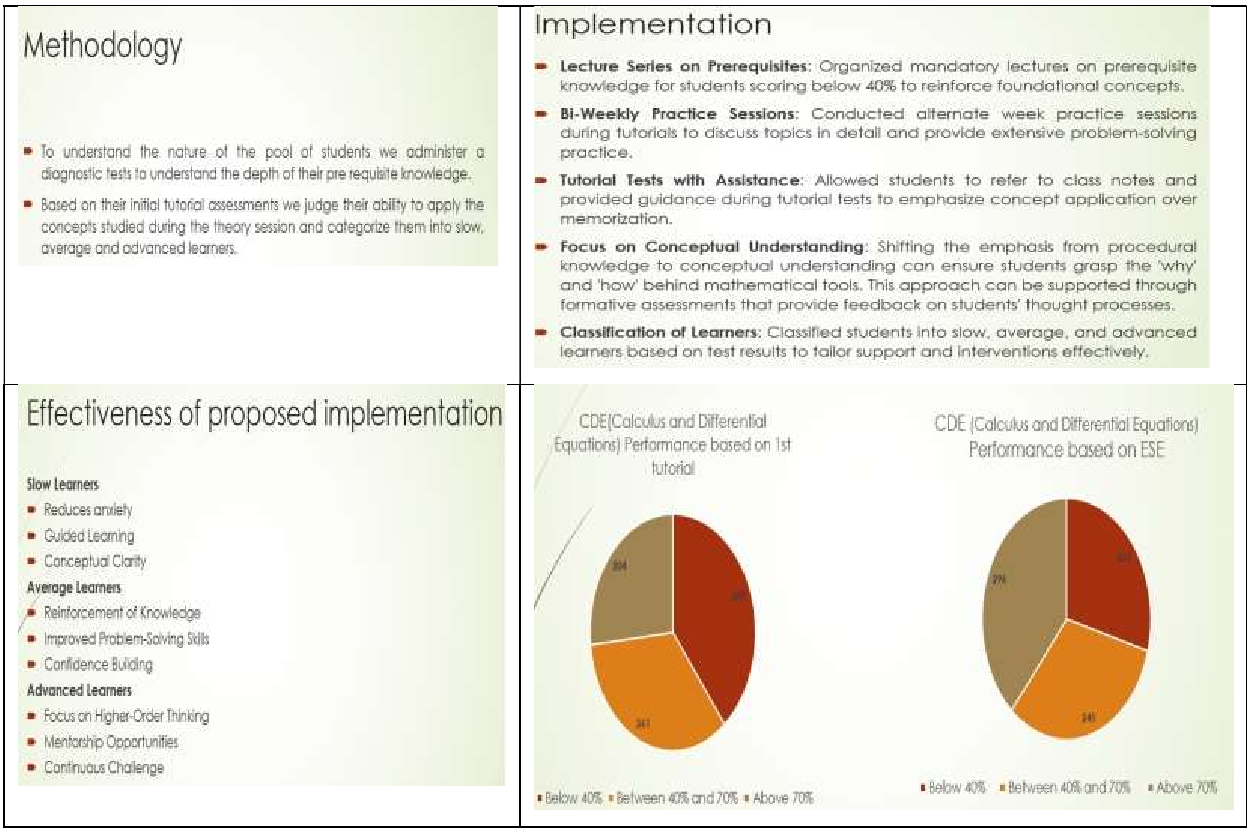
graphics, and mathematical modeling, culminating in animated video projects. The activity successfully improved students' understanding of abstract concepts, programming skills, and collaboration. It proved to be an engaging and scalable initiative suitable for implementation at college level.

The students' projects are available in the following link.

https://www.youtube.com/@vertex-gdna

Analysis

- **Active Learning Approach: Implementing an Active Learning approach in teaching methods to make mathematics more accessible without losing its rigor.**



Proposed Pedagogical Innovations

(i) Competency based micro credentials:

Break large courses into modules focusing on competencies like calculus foundations and linear algebra and offer micro-credentials for mastered skills, aligning with NEP's flexibility. Implementation should map competencies to measurable outcomes.

(ii) Work book concept:

Initiate the preparation of practice problems in worksheet with detailed procedure. Add some case studies to compare and study. Also add discussion with peers for their views after studying the particular concept.

(iii) Integrated Multidisciplinary Projects and Lab-Driven Learning:

Create semester-long, team-based projects where mathematics is a central tool for tasks such as modeling and simulations, aligning with NEP's focus on experiential learning.

(iv) Flipped + Mastery Approach:

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Combine the flipped classroom model with mastery learning through formative quizzes and adaptive practice, ensuring students achieve foundational skills before moving forward.

(v) Adaptive Learning Systems & AI Tutors:

Use platforms that adjust problem difficulty and offer targeted support; AI tutors can provide personalized hints, promoting fairness and accommodating diverse learning levels.

(vi) Assessment Reform:

Formative, Authentic, and Competency-Based Assessments (for slow learners): -Shift from high-stakes exams to multiple low-stakes formative assessments, Align evaluation criteria with learning outcomes.

(vii) Data-Driven Pedagogy:

(a) Leverage learning analytics to improve teaching. (b)Identify at- risk students early and offer remediation in foundational mathematics (Slow, Average).

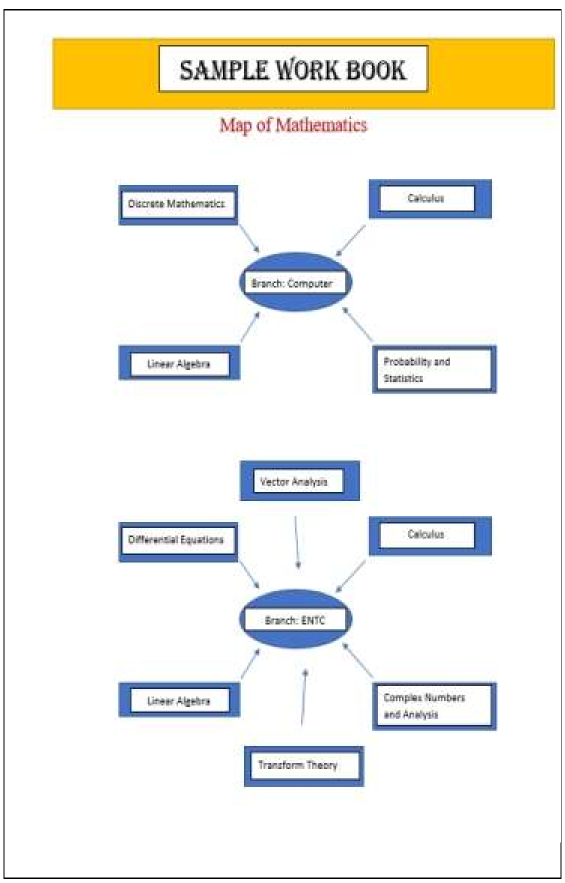
(vii) Faculty Development & Communities of Practice:

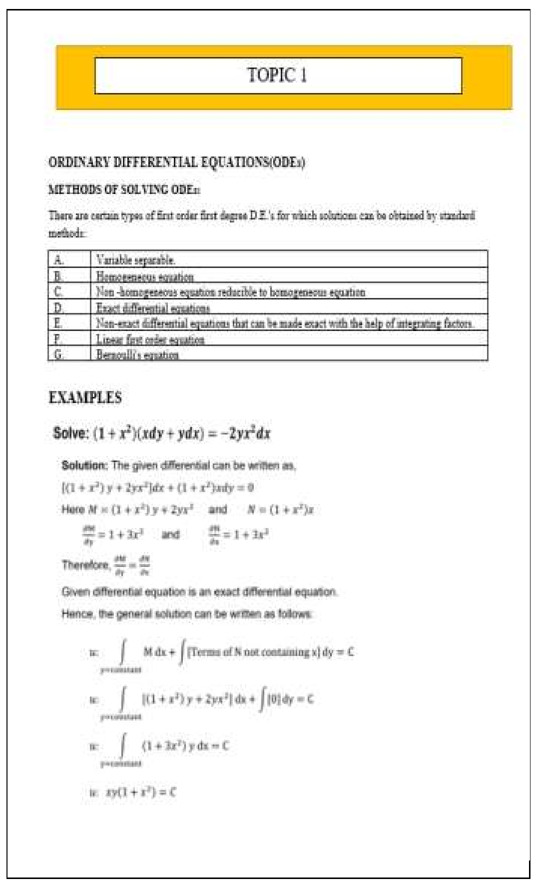
Invest in ongoing teacher training in instructional design, digital pedagogy, and assessment methods. Recognize and reward teaching innovation.

(vii) National / Institutional Open Educational Resources and Shared Repositories:

In line with NEP's call for digital resources, create organized, peer-reviewed multimedia materials for Engineering Mathematics accessible to all institutions.

A sample of Workbook is as shown below (Problems are taken from Higher engineering mathematics by B.V. Ramana)





TOPIC 1

ORDINARY DIFFERENTIAL EQUATIONS(ODEs)

METHODS OF SOLVING ODEs:

There are certain types of first order first degree D.E.'s for which solutions can be obtained by standard methods:

A.	Variable separable.
B.	Homogeneous equation
C.	Non -homogeneous equation reducible to homogeneous equation
D.	Exact differential equations
E.	Non-exact differential equations that can be made exact with the help of integrating factors.
F.	Linear first order equation
G.	Bernoulli's equation

EXAMPLES

Solve: $(1+x^2)(xdy+ydx) = -2yx^2dx$

Solution: The given differential can be written as,

$[(1+x^2)y+2yx^2]dx+(1+x^2)xdy=0$

Here $M=(1+x^2)y+2yx^2$ and $N=(1+x^2)x$

$\frac{\partial M}{\partial y}=1+3x^2$ and $\frac{\partial N}{\partial x}=1+3x^2$

Therefore, $\frac{\partial M}{\partial y}=\frac{\partial N}{\partial x}$

Given differential equation is an exact differential equation.

Hence, the general solution can be written as follows:

ie: $\int_{y=constant} M\,dx+\int[\text{Terms of N not containing x}]\,dy=C$

ie: $\int_{y=constant} [(1+x^2)y+2yx^2]\,dx+\int[0]\,dy=C$

ie: $\int_{y=constant} (1+3x^2)\,y\,dx=C$

ie: $xy(1+x^2)=C$

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PRACTICE PROBLEMS

APPLICATIONS

1)

When a resistance R ohm is connected in series with an inductance L Henries and an emf of E volt, the current 'i' amperes at time 't' is given by $L\frac{di}{dt} + Ri = E$. If $E = 10\sin t$ volts and i=0 when t=0 then find "i" as a function of t.

2)

A tank contains 50 gallons of a solution composed of 75% water and 25% alcohol. A second solution containing half water and half alcohol is added to the tank at the rate of 3 gallons per minutes. At the same time, the tank is being drained at the same rate. Assuming that the solution is stirred constantly, how much alcohol will be in the tank after 10 minutes?

CASE STUDIES

1)Modeling the Epidemiological Spread of Disease: A Mathematical Approach for First-Year Engineering Students.

Future Pedagogical Directions in Engineering Mathematics

(i) AI-Enabled Adaptive Learning

(a) Utilize AI-powered platforms to create personalized practice sets, adapt to a student's pace, and deliver immediate feedback.

(b) Systems such as AI tutors can identify misconceptions in subjects like calculus and provide targeted assistance.

(c) This approach ensures inclusivity, supporting both slow learners with scaffolding and advanced students looking to go beyond the syllabus.

(ii) Integration of Mathematics with Multidisciplinary Projects

Future teaching will incorporate mathematics into engineering design challenges (Mathematics Faculties should be included in the projects from second year onwards) .For example, using differential equations in fluid mechanics simulations , linear algebra in robotics/AI/ML/Data science, Graph theory in Networking.

(iii) Immersive and Visualization Tools

Use AR and VR to visualize complex concepts like surfaces or vector fields, helping students connect abstract math to practical engineering applications.

(iv)Authentic, Competency-Based Assessment

(a)Move away from traditional exams for second and higher year from focused on rote learning.

(b)Future assessments will emphasize:

- Mathematical modeling reports
- Problems connected to industry scenarios

(c) Combining automated assessment tools with human grading will ensure fairness

(v)Collaborative and Peer-Led Learning

(a)Facilitate learning within peer groups focused on solving open-ended engineering challenges.

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(b)Peer explanations deepen understanding, aligning with NEP's goals of collaborative learning.

(vii) Faculty Development and Pedagogical Scholarship

(a)Educators will require training not just in mathematics, but also in educational technology and instructional design.

(b)Encourage action research, allowing teachers to study their own practices and share results.

(c)Institutions should support communities for math educators to grow together.

(viii)Global and Local Integration

(a)Future teaching will merge global educational resources with local challenges, focusing on Indian engineering problems. Signing MoUs with industry for training them how to use mathematics skills properly in the required areas.

(ix)Sustainability & NEP Vision

(a)NEP aims for a holistic education. Future mathematics teaching will emphasize:

- Critical thinking over memorization
- Creativity in using math for design
- Sustainability through math-driven solutions in areas like climate and health engineering.

Challenges and Mitigation Strategies :

(i) Faculty Workload & Resistance: Address with phased implementation, training, and recognition for efforts.

(ii)Resource Constraints: Use shared online resources and low-cost computational tools.

(iii)Assessment Validity: Combine automated assessments with human evaluation; research new assessment validity.

(iv) Ensuring Foundational skills: Require mastery gateways for essential skills during the first year.

Conclusion

Aligning engineering mathematics teaching with NEP 2020 demands a systemic shift. We must keep lectures to active, competency-based, and digitally-enabled learning that places mathematics in engineering contexts. The effectiveness of flipped classrooms, project-based learning, blended approaches, and active pedagogy when properly implemented and supported. The future indicates a move toward adaptive AI tutoring, competency based micro credentials and significant assessment reform. Institutions need to invest in faculty development, infrastructure, and foster a culture that values teaching innovation.

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