International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 11 | Nov - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

A Multidisciplinary, Skill-Focused Pedagogical Framework for Interactive and Experiential Learning in Mechatronics Engineering

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Abstract

In this paper, we propose an interactive teaching and learning pedagogy that combines multidisciplinary design thinking with digital technologies to help students understand and solve real-life problems. The importance of activity-based learning is particularly relevant in higher education, especially in Bachelor of Technology (B.Tech.) programs such as Mechatronics Engineering. The proposed interactive and multidisciplinary pedagogy aims to create a more engaging and student-centered learning environment. By bringing together activity-based learning, design thinking, collaboration, and digital technology, the approach can help Mechatronics Engineering students develop both technical and creative abilities and prepare them to address complex real-life engineering challenges.

Key words: Design thinking, multidisciplinary, learning, higher education

1. Introduction

At present, the Indian education system in the higher education sector is mainly fact-based teaching through lectures and preparing students to pass the examinations. The passive teaching methods in higher education have become stagnant over a period of time. Therefore, a well thought-out pedagogy that shifts the focus from CGPA/percentage to learning is required in the higher education sector to improve the teaching and learning strategy. As per recent data from AISHE (All India Survey on Higher Education), the estimated number of students enrolled in higher education is close to 40 million [1]. As the fast-changing pace of modern technology, work culture and professional career is placing new demands on these undergraduate/post graduate students, Our traditional fact-based passive lecturing methodology needs to change and new technology-enhanced interactive interdisciplinary teaching and learning pedagogy should be adopted which can foster valuable skill-set such as problem-solving, design thinking and creative ability in the students and develop their mindset to face real-life complex challenges.The research shows that interactive learning methods are significantly better in terms of teaching new skills as compared to traditional lecture-based teaching methods [2-4]. In the interactive mode of teaching, students participate in research-based activities, design experiments, discussions/case studies, and learn to think independently. Active learning methods enhance the effectiveness of teaching and instruction and impart a deep understanding of fundamental concepts [5-7].

In the context of laboratory teaching, students usually follow a set of instructions to perform the experiment in order to produce the desired outcome. In this new learning mode, students will learn to design their own concepts/experiments and solve real life problems. Visualization of a concept helps in better understanding, usability and hence boosting the imagination and creativity of students..

B.Tech Course in Mechatronics Engineering (is an integration of Mechanical, Electrical, Electronics, Control Engineering, Instrumentation and Computer Science) requires a multidisciplinary approach to understand product and manufacturing system design. The products and systems have undergone a drastic change due to the fast changing pace of modern technology (especially in microelectronics and Computer Science) in the last decade. The Industrial products are highly multidisciplinary and need Engineers with multidisciplinary knowledge. The work culture and professional career is placing new demands on B.Tech students and therefore, traditional fact-based passive lecturing methodology need to be replaced with new *technology-enhanced multidisciplinary skill-focused teaching and learning pedagogy* which can foster valuable skill-set such as *problem-solving, design thinking and creative ability* in our students.

Academics-oriented education helps in understanding the concepts behind the technology or science but skill development will help in creating solutions and products. The research shows that interactive learning methods are significantly better in terms of teaching new skills as compared to traditional lecture-based teaching methods [1-2]. In the interactive mode of teaching, students participate in research based activities, designing experiments,

discussions/case studies and learn to think independently [3]. Active learning methods enhance the effectiveness of teaching and instruction and impart deep understanding of fundamental concepts.[4].

Digital technology has already shown promising avenues in the education sector [8]. A better teaching and learning environment can be created with the multidisciplinary design thinking approach utilizing digital transformation

2. Implementation work: Following activities are required for implementation of this innovative teaching pedagogy.

2.1 Need to update the pattern of the Curriculum:

- There is a need to develop Industry-Academia syllabus. **Each** course Should include/incorporate real life practical applications of concepts in the syllabus. Experts from industry may be called for designing/updating of syllabus so that students may be in touch with the latest technological industrial innovations.
- The ratio of theory to practical should be 30 to 70so as to increase the importance of practical based learning. B.Tech Mechatronics must have 2-3 Design/Workshop courses: one in Electronics, one in Mechanical and one in Computers. *Latest research trends* should be part of each unit.
- Final semester should have only major projects and no theory subject so that students can concentrate better on the project.
- Two internship programs in the summer breaks should be of *2-3 credit* and not just one credit and should be given more importance.Students should be able to do the *live-project* during their internship program.

2.2 Laboratory infrastructure development to create experimental space:

- B.Tech students should know the Mechatronics from its fundamentals to advance level. For this our labs should be state-of-art labs. Broadly Mechatronics labs should have Electrical, Electronics, Mechanical, PLC Lab, Industrial Automation, Computer lab and PC based Measurement lab and these labs should have the full-fledged facility to develop the simple and advanced level projects.

- All the concepts taught as theory in the classroom should be supplemented with ***hands-on training*** in the lab. For example in the Electronics/Electrical lab, students must *design their own experiments* on *Bread-Boards using components, ICs, power supply etc. and* ***not just readymade kits.***This is the best way to study electronics circuits.

- **Collaboration with Industry and Other Institutes:** Collaboration with Industry opens up new avenues for students.Students expand their knowledge base and learn to use the practical knowledge in authentic and relevant real-world scenarios and contexts. Centre of Excellence set ups in all campuses of DSEU will enable our students to work in any of this center to accomplish his/her project work. We may invite big technological giants like ***BOSCH, FANUC, SIEMENS, ALLEN BRADELY, HEAVELLS, and KUKAS*** to establish their Centre in DSEU campuses.

- ***I-STEM*** is one such approach of collaboration developed for institutes and students to use scientific facilities available in India [5].Some companies such as FANUC may offer to develop the Mechatronics labs according to industry standard under CSIR activity. MOU may be signed.

2.3 Teaching Methodology : Following points are required to upgrade the teaching methods:

2.3.1 Competency of Teachers Capacity building of teachers is extremely important to ensure that they are regularly updated with the latest developments in the subjects.Our teaching methodologies are far behind the industry requirements today. In order to fill this gap, training of Teachers teaching in B.Tech (Mechatronics) is required on latest developments in the field such as: *Design thinking, Machine Learning/Deep Learning/Artificial Intelligence (How to leverage ML/AI in teaching Mechatronics) , 3D printing technology (*

Use of 3D printing/additive manufacturing in product development), Advanced Robotics (Designing advance bots for industrial applications),Virtual/Augmented reality ,Internet of Things based projects, Computer Vision, Advance level training on CNC Machines, Programmable Logic Controller and SCADA. Building an active hands-on skill focused learning experience for students and teachers is the core of this pedagogy. Following teaching approaches may be adopted while execution of this pedagogy:

- **Activity based Hands-on learning:** Teachers may use real-world experiences to demonstrate abstract concepts. Design-your–own-experiments/case studies in a team create a conducive environment for learning. There should be more emphasis on hands-on learning. Creating a device gives students the better appreciation and understanding of how the equipment works.
- Makers-space is a nice concept where students learn to build products/ devices [6].
- Students should be encouraged to participate and organize Hackathons/startup competitions.
- Participation in Clubs/Student chapters such as IEEE,REDX (reengineering, design and execution), SAEetc.

2.3.2 Multidisciplinary approach: At B.Tech (Mechatronics) level, subjects are interconnected and therefore an Interdisciplinary/multidisciplinary approach is required for clear understanding of the concepts. For example-

- *If Fourier series/transform is taught in mathematics class, its application in signal and image processing must be discussed using relevant examples.*
- *When OP Amps are taught in the Electronics design class, students must be able to design the application such as designing of a sensor using amplifier.*
- Courses such as Advance Manufacturing must be taught as per Industry standards. Students should be able to make real life practical hardware at par with the industry standards and *not just prototype*.

2.3.3 Research Inclusive approach to solve real life problems: Latest research trends related to each chapter should be discussed. Students need to find the solution for an existing relevant problem of society/environment. Students should be encouraged to fabricate the *'projects in public interest'* like *new generation mobile phones, Traffic control problem, Energy saving projects, Electric vehicle projects, UAV-Drones with specific applications, Improvement of irrigations, Health consciousness projects etc.* Students should be made Industry-Ready to face any interview during their placement.

2.3.4.Change in examination/evaluation patterns:

- Short, more frequent and application based tests would encourage students and teachers to focus on application oriented learning.
- Open book testing (aimed at testing the depth of understanding and also at creativity, rather than focusing on the memory strength of an individual) should be introduced.
- Class assignments should be challenging and thought/idea provoking to ensure the students engage well and have a steeper learning curve.

2.3.5 *International Student exchange Program* such as DAAD (Germany) must be there in the third year of the B.Tech program to provide international exposure to our students.

2.3.6 Incubation/Start-ups: Students must learn to innovate and build their startup using innovative design thinking approach of this pedagogy.

2.3.7 Feedback and Quality check: The institute must complete the criteria to get the NBA Accreditation (Update of number of faculty, Creation of adequate labs, infrastructure, 100 % placements etc.)forB.Tech courses and get the Courses equivalent to International Engineering courses. Reward and Recognition should be given to students, faculty and Alumni for Innovative Projects. The teachers should be promoted based on innovations introduced during a year and the *semester feedback taken from students* for teaching. ISO Audits should be done for the institute on a regular basis to ensure the quality of the education.

3. Outcomes:

With appropriately using the activity based learning, students will be able to have confidence about the correct way of learning and building new things. Following are some of the outcomes of this pedagogy:

- **Creative ability and critical thinking**: This multidisciplinary *design thinking approach* of interactive teaching and learning pedagogy enhances the *creative ability and critical thinking* of students, inculcate *problem solving habits* and makes them future ready to face the global challenges of the world.
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- **Communication and collaboration skills**: Students will learn to work in teams, *communicate/collaborate better and develop emotional compatibility* with each other.
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- **New Ideas generation/Startups:** Students will be able to generate new ideas and apply them to make products/services in real world scenarios. Solving real world issues and problems generate a sense of *responsibility* and *ethics* in them. With such innovative training, students may build their startups in future as well.
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- **Risk taking and Leadership:** Learning to build and creating things on their own develop the *leadership quality and risk-taking ability* in students.
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- **Digital compatibility:** Students will be well-versed with the new digitally transformed learning techniques and utilize this knowledge for their professional achievement.

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