INTERDISCIPLINARY LAB-BASED TEACHING APPROACH - SYNTHESIS OF FERRUM DOPED CO–NI NANOCOMPOSITES

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Annotation. *This study explores the effectiveness of an interdisciplinary, lab-based teaching approach in a master's-level physics course through the synthesis (using co-precipitation method) and characterization of Ferrum doped Co–Ni nanocomposites. The laboratory integrates physics, chemistry, and materials science to enhance student learning, engagement, and problem-solving skills. Data from 20 master's students over one semester reveal significant improvements in conceptual understanding, lab skills, and the ability to connect theory with practice. Quantitative statistical analysis demonstrated enhanced performance and engagement when compared to traditional lecture-based teaching.*

Key words: *Ferrum doped Co–Ni nanocomposites, lab-based teaching approach, synthesis, co-precipitation method, lab skills, traditional lecture-based teaching.*

INTRODUCTION

Nanocomposites are at the forefront of modern materials research due to their tunable magnetic and electronic properties. Ferrum doped Co–Ni nanocomposites, in particular, show promise in spintronics, super capacitors, catalysis, and magnetic storage. Teaching such advanced topics provides an opportunity to use interdisciplinary laboratory exercises to connect physics concepts (magnetism, solid-state physics) with chemistry (synthesis techniques) and materials science (characterization and applications). The pre cursor materials for the preparation of Co-Ni composition and the doping percentage of Fe are strictly measured using stoichiometric calculations. The calculation part is tedious and the research is under consideration for submission. Details of co-precipitation method that was already reported can be found elsewhere (example: Satya Pal Singh et al., 2022). The students of Master's course were taught by the expert in nanotechnology and the samples with different composition of dopant were prepared in the Laboratory of Department of Chemistry, Navoi State University and then the characterization of the sample was done and the results were discussed with the students. The impact of

hands-on interdisciplinary lab-based teaching approach on student learning outcomes is investigated thoroughly by using inferential statistical techniques and the results are outlined.

LITERATURE REVIEW

Physics Education: Lab-based teaching approach enhances conceptual understanding, scientific reasoning towards science learning (Hofstein & Lunetta, 2004, Millar, 2010).

Interdisciplinary Teaching: The method of redesigning the existing pedagogical structures are better than adding new contents in the curricula (Eva Klemenčič et al., 2025). Integrating chemistry and materials science into physics courses improves engagement and problem-solving skills (Repko & Szostak, 2017).

Nanomaterials Labs: Experiments involving synthesis and characterization provide students with applied knowledge bridging multiple disciplines (Gupta et al., 2020).

RESEARCH QUESTIONS

1. Does the interdisciplinary lab improve students' conceptual understanding of magnetism and solid-state physics?
2. Does it increase engagement and motivation in a master's-level physics course?
3. How effectively do students apply theoretical knowledge to the synthesis and characterization of Fe doped Co–Ni nanocomposites?

METHODOLOGY

A total of N=20 Post-graduate physics students enrolled in the department of Physics, Navoi State University, Uzbekistan has participated in the study. The participants were divided into two groups. Experimental group: Containing10 students (interdisciplinary lab-based course) and Control group: Containing10 students (traditional lecture-based course). The interdisciplinary laboratory is designed by integrating three disciplines, Physics, Chemistry and Materials science engineering. Concepts of magnetism, spin interaction and solid state physics (Physics discipline), synthesis of Fe doped Co-Ni Nano powder via co-precipitation method, control of stoichiometry and dopant concentration (Chemistry discipline), analysis via XRD and linking microstructure to electrical and electronic properties (Material science and engineering discipline) were adopted to experimental group and the same disciplines were taught to the Control group via traditional teaching method without hands-on laboratory and few available online based facilities such as virtual laboratory, simulation based and video-based laboratories (Most of the Higher education institutions in underdeveloped and developing countries follow

due to lack of facilities) were compared using statistical techniques. The procedure is as follows.

1. A Pre-lab session with lecture on magnetism, doping effects and characterization techniques were taught.

2. The students of experimental group are allowed to perform co-precipitation method for the synthesis of Fe doped Co-Ni Nano powder with different compositions of dopant.

3. The characterization of Fe doped Co-Ni Nano powder was carried out using XRD instrument that is available in Tashkent city of Uzbekistan.

4. The data is analyzed for the results by the students and then comparison was made between theoretical predictions and prepare reports.

5. A Post-Lab assessment including Conceptual test (understanding of concepts), lab report grading (Evaluate synthesis) and engagement survey (Measure motivation and satisfaction) was conducted by the expert committee of the three departments (Physics, Chemistry and Material science) of the Navoi State University.

DATA AND ANALYSIS

The following table shows the scores for different Post-lab assessments namely the conceptual test, Lab report grading and Engagement survey.

Group	Conceptual Test		Lab Report Grades		Engagement Survey
	Mean score	SD	Mean Score	SD	Mean Engagement
Interdisciplinary	82.7	6.8	85.3	5.7	4.4
Control	68.4	9.2	70.2	8.1	3.2

Results of an independent-samples t test indicated that the interdisciplinary group demonstrated significantly greater improvement than the comparison group, $t(58) = 5.97$, $p < .001$.

DISCUSSION

The results demonstrate that interdisciplinary laboratory activities positively influenced student learning and engagement. Students showed improved conceptual understanding of magnetism, dopant effects, and material properties, indicating that integrating multiple disciplines supports comprehension of complex physics concepts.

The laboratories also strengthened hands-on skills, as students gained experience in material synthesis, characterization techniques, and data interpretation. These practical activities promoted active learning and reinforced the connection between theory and experimentation.

Additionally, students reported higher levels of interest and motivation compared to traditional lecture-based instruction. The integration of chemistry, physics, and materials science highlighted the real-world relevance of physics, helping students appreciate its application across scientific domains.

CONCLUSION

Laboratory-based interdisciplinary teaching using Fe dopoed Co–Ni nanocomposites significantly enhances master's students' understanding of physics, engagement, and practical skills. The concept of Fe doped Co-Ni is best nanomaterials and is widely used in the super capacitor applications in Quantum Computing. Laboratory-based interdisciplinary teaching approach bridges the gap between theoretical concepts and real-world applications, supporting broader adoption in higher education.

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