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TRANSFORMING PHYSICS EDUCATION THROUGH AI-ASSISTED AND EXPERIENTIAL LEARNING: INTEGRATING NEP 2020, INDIAN KNOWLEDGE SYSTEMS AND DIGITAL PEDAGOGY

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ABSTRACT

Physics is a discipline that develops scientific reasoning through observation, experimentation, mathematical interpretation and the exploration of natural phenomena. However, conventional approaches to physics teaching often place greater emphasis on theoretical explanations, mathematical derivations and examination-oriented learning than on conceptual understanding and practical application. The emergence of artificial intelligence (AI), digital learning environments and experiential pedagogies offers new possibilities for addressing these limitations. At the same time, India's National Education Policy (NEP) 2020 calls for multidisciplinary education, critical thinking, experiential learning, technological integration and the incorporation of Indian Knowledge Systems (IKS) into contemporary educational practices.

This paper examines how AI-assisted learning and experiential teaching strategies can contribute to the transformation of physics education in Indian higher education institutions. It explores the educational applications of generative AI, intelligent tutoring systems, virtual laboratories, interactive simulations and digital assessment tools. Particular attention is given to connecting modern physics concepts with traditional Indian scientific contributions, including astronomical observations, mathematical developments, time measurement and indigenous technological practices. The paper proposes an integrated pedagogical framework in which AI functions as a supportive educational resource rather than a replacement for teachers, laboratory experiences or independent scientific reasoning. It also discusses challenges associated with unequal digital access, scientific accuracy, academic integrity, teacher preparedness and responsible use of technology. The study argues that combining technological innovation with experiential learning and culturally grounded knowledge can make physics education more engaging, inclusive, relevant and meaningful.

Keywords: Artificial Intelligence, Physics Education, NEP 2020, Experiential Learning, Indian Knowledge Systems, Digital Pedagogy, Higher Education, Virtual Laboratories.

1. INTRODUCTION

Physics provides a fundamental understanding of the natural world, from the motion of everyday objects to the behaviour of atoms, molecules and complex technological systems. Its significance extends beyond academic study because the principles of physics underpin developments in communication, renewable energy, medical imaging, electronics, nanotechnology and space exploration. Despite its importance, physics is frequently perceived by students as a difficult subject because of its mathematical requirements, abstract concepts and limited opportunities to connect theoretical knowledge with everyday experiences.

Traditional classroom teaching, although valuable for developing foundational knowledge, may not always provide sufficient opportunities for active participation, scientific investigation and independent exploration. Students sometimes learn formulae and derivations without developing a clear understanding of the physical processes represented by them. This creates a gap between knowing scientific information and applying scientific principles to real-life situations.

The rapid development of artificial intelligence has introduced new possibilities for addressing this challenge. AI-supported educational platforms can provide personalised explanations, interactive learning activities, immediate feedback and opportunities for self-directed learning. Digital simulations and virtual laboratories can further help students visualise phenomena that are difficult, expensive or unsafe to reproduce in conventional laboratories.

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However, technological integration alone cannot transform education. Meaningful improvement requires a pedagogical approach that combines scientific understanding, experimentation, critical thinking and human interaction.

India's National Education Policy 2020 provides an important foundation for transforming the higher education system by emphasising conceptual understanding, critical thinking, experiential learning, multidisciplinary education and technological integration (Ministry of Human Resource Development, 2020). These priorities create opportunities to connect contemporary physics education with indigenous scientific traditions while preparing students for an increasingly technology-driven society [1].

The present paper therefore explores an integrated approach to physics teaching in which AI-assisted instruction, experiential learning, NEP 2020 principles and IKS are brought together to develop a more student-centred educational environment.

2. OBJECTIVES OF THE STUDY

The major objectives of this paper are:

1. To examine the potential of artificial intelligence in improving the teaching and learning of physics.
2. To explore experiential and activity-based approaches for developing conceptual understanding and scientific skills.
3. To analyse the relevance of NEP 2020 in promoting innovative and multidisciplinary physics education.
4. To identify opportunities for integrating Indian Knowledge Systems with contemporary physics concepts.
5. To propose an integrated pedagogical framework suitable for undergraduate physics education.
6. To discuss the challenges and ethical considerations associated with the adoption of AI-based educational practices.

3. RESEARCH METHODOLOGY

The present study adopts a conceptual and analytical approach based on a review of relevant policy documents, published research and literature concerning artificial intelligence, science education, experiential learning and digital pedagogy. The National Education Policy 2020 and UNESCO's guidance on generative AI in education and research provide important policy and ethical foundations.

Relevant literature on active learning and AI-supported science education is examined to identify pedagogical opportunities, limitations and areas requiring further investigation. The discussion also draws upon the educational relevance of selected Indian scientific traditions.

Rather than presenting original experimental findings, the paper develops an integrated conceptual framework for the effective use of AI-assisted and experiential approaches in undergraduate physics education.

4. ARTIFICIAL INTELLIGENCE AS AN EMERGING TOOL IN PHYSICS EDUCATION

Artificial intelligence has the potential to change the way students interact with scientific knowledge. Unlike conventional digital resources that generally present fixed learning materials, AI-supported platforms can respond to individual questions, provide alternative explanations and adapt learning activities according to students' needs.

Physics involves several concepts that require visualisation and repeated explanation. Topics such as electromagnetic induction, wave interference, quantum phenomena, rotational dynamics and semiconductor physics may be difficult to understand through verbal explanations alone. AI-based educational systems can support these topics through interactive illustrations, simplified explanations, guided problem-solving and personalised feedback.

4.1 Personalised Learning and Intelligent Tutoring

Students in a classroom do not necessarily learn at the same pace. Some may understand mathematical derivations quickly but experience difficulty with conceptual applications, while others may require additional explanations of basic principles.

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Recent developments in artificial intelligence have created new possibilities for personalised instruction, adaptive learning and student-centred educational practices. AI-based educational tools can support learners through interactive explanations, immediate feedback and customised learning experiences [2].

AI-assisted learning tools can provide different levels of explanation according to individual learning requirements. For example, while teaching Newton's laws of motion, an AI-supported platform may explain the concept through everyday examples, numerical problems, graphical representations and progressively challenging exercises.

4.2 AI-Assisted Problem Solving

Numerical problem-solving is an essential component of physics education. AI-based platforms can guide students through the stages of identifying physical quantities, selecting appropriate equations, substituting numerical values and interpreting final results.

The educational value of these systems lies not simply in producing correct answers but in explaining the reasoning behind each step. Teachers can encourage students to compare AI-generated solutions with their own calculations, identify differences and verify results through established physical laws.

This practice can develop analytical thinking and scientific scepticism. Students should be encouraged to question AI-generated responses rather than accept them without verification.

4.3 AI in Assessment and Academic Feedback

Conventional assessment often provides feedback after the completion of an assignment or examination. AI-supported assessment systems can provide quicker responses and help identify recurring conceptual difficulties.

However, the integration of generative AI into education requires appropriate attention to scientific accuracy, transparency, academic integrity and human supervision [3].

5. EXPERIENTIAL LEARNING: CONNECTING PHYSICS WITH EVERYDAY LIFE

Experiential learning provides students with opportunities to understand scientific concepts through direct observation, experimentation, investigation and reflection. It shifts the focus from passive reception of information towards active participation in the learning process.

Physics is particularly suitable for experiential approaches because its principles can be observed in numerous everyday situations.

The importance of active learning is also supported by Freeman et al. (2014), whose meta-analysis demonstrated improved student performance in science, technology, engineering and mathematics through active learning approaches compared with traditional lecturing [4].

5.1 Activity-Based Classroom Learning

Teachers can incorporate short activities into regular lectures without requiring expensive equipment. Simple demonstrations using magnets, batteries, wires, mirrors, water, pendulums and mobile-phone sensors can make physics concepts more accessible.

5.2 Virtual Laboratories and Digital Simulations

Virtual laboratories provide an additional opportunity to explore scientific concepts through computer-based experiments. Interactive simulation platforms such as PhET allow students to modify experimental parameters and observe corresponding changes in physical systems.

Platforms such as PhET Interactive Simulations provide interactive environments in which students can investigate physical phenomena by changing variables and observing their effects. Such resources can support conceptual understanding through visualisation and exploration [5].

Virtual laboratories are particularly useful when laboratory facilities are limited or when an experiment requires equipment that may not be readily available.

5.3 Project-Based and Community-Oriented Learning

Physics education can become more meaningful when students investigate problems related to their surroundings.

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Undergraduate students can undertake small projects on solar energy utilisation, household electricity consumption, energy-efficient lighting, sound pollution, water heating and the working principles of common electronic devices.

These projects connect classroom learning with sustainable development and encourage students to apply scientific knowledge to practical challenges.

6. NEP 2020 AND THE TRANSFORMATION OF PHYSICS EDUCATION

The National Education Policy 2020 provides a broad vision for developing an inclusive, flexible and multidisciplinary education system. Its emphasis on conceptual understanding, critical thinking, creativity and experiential learning is particularly relevant to physics education.

The policy encourages a movement away from rote memorisation towards deeper learning and practical application. This requires teachers to reconsider how scientific concepts are introduced, discussed, assessed and connected with other disciplines.

In undergraduate physics programmes, the principles of NEP 2020 can be implemented through:

- Activity-based teaching and laboratory-centred learning.
- Interdisciplinary courses connecting physics with chemistry, mathematics, biology and computer science.
- Skill-oriented courses involving instrumentation and electronic devices.
- Project-based assignments and problem-solving activities.
- Digital learning resources and flexible assessment strategies.
- Integration of Indian Knowledge Systems into relevant scientific topics.

7. INTEGRATING INDIAN KNOWLEDGE SYSTEMS WITH MODERN PHYSICS

Indian Knowledge Systems represent a diverse body of intellectual and practical traditions developed through centuries of observation, experimentation, mathematical reasoning and technological activity. Their educational integration should be undertaken through historically informed and scientifically responsible approaches.

The National Curriculum Framework for School Education 2023 provides an important educational context for integrating Indian Knowledge Systems into contemporary learning. Such integration can encourage students to explore India's intellectual traditions while developing historical awareness and critical understanding (National Council of Educational Research and Training, 2023) [6].

Rather than presenting traditional knowledge as a substitute for modern scientific methods, teachers can use it as a contextual resource for exploring the development of human understanding of nature.

7.1 Astronomy and Mathematical Traditions

Indian astronomers and mathematicians made important contributions to mathematical astronomy and the study of celestial movements.

The works associated with Aryabhata, Varahamihira and Bhaskara II provide opportunities to discuss historical approaches to planetary motion, astronomical calculations, eclipses, calendars and mathematical methods.

7.2 Time Measurement and Traditional Instruments

Traditional Indian astronomical instruments and observational methods offer interesting examples of the relationship between geometry, light and measurement.

Sundials and shadow-based instruments can be used to introduce concepts such as the rectilinear propagation of light, the formation of shadows, angular measurement and the apparent motion of the Sun.

7.3 Traditional Materials and Metallurgical Knowledge

India has a rich history of metallurgy, metalworking and material processing. Traditional furnaces, metal extraction and the development of durable metallic objects provide contextual opportunities to discuss heat transfer, thermal properties, material structure and chemical processes.

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7.3 Developing Scientific Appreciation Through IKS

Integrating IKS into physics education can help students appreciate the historical development of scientific ideas and the importance of observation and systematic inquiry.

It can also encourage interdisciplinary discussions involving physics, history, mathematics, philosophy and technology.

8. PROPOSED INTEGRATED PEDAGOGICAL FRAMEWORK

The integration of AI, experiential learning, NEP 2020 and IKS requires a structured teaching approach. The present paper proposes a four-dimensional framework for undergraduate physics education.

Dimension I: Conceptual Foundation

Teachers introduce fundamental scientific principles through classroom discussion, mathematical explanations and real-life examples. The focus remains on developing conceptual clarity before introducing advanced applications.

Dimension II: AI-Assisted Learning

Students use AI-supported educational tools for additional explanations, guided problem-solving, self-assessment and revision. Teachers guide students in verifying the accuracy of AI-generated responses and identifying possible errors.

Dimension III: Experiential and Experimental Learning

Students participate in demonstrations, laboratory activities, virtual simulations, field observations and small projects. They record observations, analyse results and relate experimental findings to theoretical principles.

Dimension IV: Cultural and Interdisciplinary Context

Relevant IKS examples are introduced to provide historical and cultural perspectives on scientific observation, mathematics, astronomy and technological development. These examples are connected with contemporary scientific knowledge through evidence-based discussion.

The four dimensions are interconnected rather than independent stages. Their combined application can create a learning environment in which students move from understanding a concept to exploring it, questioning it and applying it.

9. CHALLENGES AND ETHICAL CONSIDERATIONS

Despite its potential, the integration of AI and digital technologies into physics education involves several challenges.

Digital inequality: Students from different socioeconomic backgrounds may not have equal access to smartphones, computers, reliable internet connectivity and digital learning platforms. Institutions should therefore provide shared digital facilities and accessible learning resources.

Scientific accuracy: AI systems may occasionally generate incorrect explanations, mathematical errors or misleading scientific interpretations. Teachers must encourage verification through textbooks, research publications and established scientific principles.

Academic integrity: Excessive dependence on AI-generated assignments and solutions may reduce independent thinking. Students should be required to explain their reasoning, demonstrate practical work and acknowledge AI assistance where institutional policies require it.

Teacher preparedness: Effective integration requires teachers to develop digital competencies, AI literacy and the ability to design meaningful learning activities. Professional development programmes are essential.

Data privacy and responsible use: Educational institutions must consider student privacy, data security, transparency and appropriate age-related safeguards when selecting AI platforms. UNESCO (2023) emphasises a human-centred approach to generative AI in education and research.

Preservation of human interaction: Education involves mentoring, encouragement, discussion and the development of values. These dimensions cannot be reduced to automated interaction. AI should support teachers rather than diminish their central educational role.

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CONCLUSION

Transforming physics education requires more than introducing new digital tools into existing classroom practices. It requires a thoughtful shift towards active, inclusive, interdisciplinary and concept-oriented learning.

Artificial intelligence can support personalised instruction, problem-solving, immediate feedback and independent learning. Experiential activities, physical experiments and virtual laboratories can strengthen the connection between theoretical knowledge and practical understanding. NEP 2020 provides a policy framework for encouraging these approaches, while Indian Knowledge Systems offer meaningful historical and cultural contexts for scientific exploration.

The integrated pedagogical framework proposed in this paper places the teacher at the centre of educational decision-making while using AI as a supporting resource. It recognises that technological innovation must be accompanied by scientific accuracy, ethical awareness, independent reasoning and practical engagement.

Future research should examine the effectiveness of this integrated framework through classroom-based interventions, comparative learning studies, teacher feedback and longitudinal assessments across different institutional settings. Such evidence would help determine how these pedagogical approaches can be adapted to diverse educational environments and contribute to the broader transformation of science education.

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