Focus on

Science, Society, and Sustainability

IMRC

Vol 2 Issue 1 |2025

Research and Development Digest

A Bilateral Knowledge Hub of India and Mexico under the aegis of Embassy of India in Mexico

Message

H E Ambassador of India to Mexico

Dr. Pankaj Sharma

India-Mexico Research Consortium (IMRC) has been initiated as a driver for disseminating the knowledge evolving through research and development on various scientific, technological, and management disciplines between India and Mexico. IMRC has organized in the past several webinars to synergize cross-country research on entrepreneurship, sustainability, engineering, and technology. Beginning a tangible effort to connect the multi-discipline research between India and Mexico through Research and Development Digest (RDD) is a new hope to bring the scientific diaspora of both countries on a single platform. RDD has entered in the second year and present this first number on Science, Society, and Sustainability on way to its academic journey. I wish the IMRC and RDD success in this academic endeavor.

In this issue…

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Editorial

Science, Society, and Sustainability: A Symbiosis of Values

Science, Society, and Sustainability (S-3) has a dynamic and symbiotic relationship between scientific endeavors and the community and protecting the sustainable ecosystem encompassing societal needs and values through scientific advancements. The perfect bonding of S-3 endeavors significantly impact culture, policy, technology, and everyday life. Such interaction involves effective science communication, the ethics of scientific practices, societal implications of technological advancements, and the role of science in addressing global issues such as agroecology, climate change, and public health. The scientific research is influenced by the societal problems, needs and expected solutions by considering priorities, resources, and ethical frameworks. In turn, scientific research provides tools, knowledge, and technologies, which builds meta-contributions to serve society and sustainability goals.

Over the centuries, India's scientific and technological position among developed and developing countries has shifted. Several centuries ago, it was characterized by scientific thought, capabilities, and techniques more advanced than many countries. Science and technology in India rest on four pillars comprising techno-nationalism, inclusive growth, techno-globalism, and global leadership.

Scientific breakthroughs over the past in India, Mexico, and among the partner countries have led to advancements in medicine, agriculture, and communication, but they can also have unintended negative consequences, such as the development of space research, artificial intelligence (AI), biotechnology agents, industrial growth booster, and sustainable agriculture. However, there exists ethical dilemmas with artificial intelligence and co-intelligence (AI-human interface). The intersection of science, society, and policy is increasingly vital, as scientific evidence informs public policy and decisions of policy makers that shape the direction of scientific research. Society and sustainability has intertwined relationships, and science mediates such convergence with meta-knowledge and meta-learning perspectives. Eco-socialist politics also thrives in solving critical problems of how to build socialism out of the material conditions that confront us involving the production construction material like steel, cement, minerals, and more (Huber, 2022).

The production and consumption patterns are associated with a wide range of sustainability issues throughout the lifecycle of product and services. The conventional industry practices in developing economies result in various social and ecological problems. Industries that pioneer sustainability consciousness in society integrate strategies to manage the ecosystem through their business models. The integrated business models with sustainability commitment can be explained in terms of their value proposition, and value creation and delivery though effective corporate social responsibility. These perspectives need to be discussed in terms of cleaner production and consumption and managing constituents of sustainable ecosystems through global-local business models (Bridgens et al., 2027).

Circular Economy (CE) has emerged as a major point of convergence as a shift in science, society, and sustainability contextuality. CE has been modelled as an industry, which encourages recycling of wastes for producing industrial products, and adheres to the global sustainability commitments. However, the conventional industrial system tends to collapse as the consumption level increases due to the scarcity of ecosystem-based resources. The circular economy has been implemented in industries such as steel, paper, polymers, and products such as mobile phones. In the various industrial sectors, the CE has shown a positive impact on resources management (Hanumante et al., 2019).

Sustainable business widely depends on environment-friendly logistics and inventory management with low carbon emissions. Refrigerated transportation and inventory are more susceptible to environmental pollution than other ways of distribution sources. Freight transportation firms are facing mounting challenges of fuel consumption and need to reduce the significant environmental imbalances that accrue from transport vehicles (Bektas et al., 2019). However, most small and medium enterprises are observing a major fix between lowering the logistics- and inventory cost and stay price competitive in the market. The operations of freight transport industry in developing economies is highly competitive due to increased production and consumption coupled with government pressures to achieve sustainability. Therefore, eco-innovation has become the principal concern among the business corporations towards following the sustainable parameters to not only satisfy stakeholders' values such as reducing negative environmental externalities, but also towards reaching governments' green requirements and consumer demands.

The intervention of scientific research is significantly increasing to improve the social quality of life and developing sustainable practices. However, the challenges in this field are also increasing alongside. Nurturing scientific understanding to foster community-driven solutions is pressing global challenges such as public health. Educating young minds is one of the most effective ways to build resilient, self-sufficient, and sustainable societies ready to confront issues of limited awareness about the microbial world, good hygiene practices, and the growing threat of antimicrobial resistance in developing economies (Agarwal et al., 2025).

As an important part of science and technology innovation, digital technology innovation profoundly impacts economic structure transformation and industrial upgrading. Metaverse is the recent technological drive for the businesses that tend to operate totally virtually. It is an evolving digital universe that blends virtual (VR) and augmented reality (AR) to create immersive experiences. An immersive experience can be defined as a neurobehavioral feel that engages in the senses, making participants feel as though they are part of the event or environment rather than just observers. This can be achieved through various technologies and methods, creating a sense of presence and involvement. However, enterprise digital technology innovation activities involve high risk and uncertainties.

Rajagopal, PhD FRSA
Editor, RDD-IMRC

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Science for Society Programs: Government of India

Science for Equity Empowerment and Development (SEED) Division (earlier known as Science and Society Division) under the Department of Science and Technology provides opportunities to motivated scientists & technologists from national Research and Development (R&D) labs, S&T-driven Non-Governmental Organizations (NGOs) and field-level workers to take up action-oriented and location-specific projects aiming at Socio-economic development of disadvantaged sections of the society through appropriate interventions of Science, Technology and Innovation (STI), leading to their improved quality of life and livelihood. Through its diverse schemes and programs, efforts are being made to empower the community by adopting technologies to address locally defined needs and priorities that consider available resources and moral prosperity of society for sustainable development. The schemes and programs of the division are also being converged with line function ministries/departments for the last-mile delivery and national development programs to achieve Sustainable Development Goals (SDGs).
Source: Department of Science and Technology, GOI
https://dst.gov.in/science-society-programmes

Government Initiatives on Science, Society and Sustainability

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The Government of India continuously works to include science, technology, and innovation for societal benefits and promote sustainable development through various government initiatives. The initiatives include continuously fostering innovation ecosystems, research and development, communication, startup culture, and societal challenges such as global warming and sustainable agriculture. The Department of Science and Technology (DST), Science and Engineering Research Board (SERB) and India Science, Technology and Innovation (ISTI) have initiated various programs and provided funding for various projects and innovations to foster science that will benefit society in the long term.

Introduction

In the 21st century, the global community confronts intertwined challenges: environmental degradation, social inequality, and rapid technological transformation. We are aware that science and technology play major role for a sustainable future in dealing with climate change, access to clean water, poverty alliviation, increase literacy rate, and increase healthcare facilities. The solution to such problems demands science and technology in today's era. In order to solve real-world problems, inclusive and sustainable governance plays a significant role. Resources for performing research to solve these problems require funding. The government can provide this funding and fellowship through various initiatives. The government continuously brings new schemes to foster research culture in India through various schemes in rural and urban regions. It focuses on how advanced technology helps society through science. The solutions to these problems must be sustained for many years. Further, the Government also focuses on launching various policies and programs, from digital governance to climate change action plans to innovation and education initiatives [2] [3] [4].

In the 2024-25 Budget, Finance Minister Nirmala Sitharaman allocated Rs 20,000 crore to the Research, Development and Innovation focused on "investing in people, the economy and innovation" in India. This initiative was announced in July 2024 by promoting private sector-led research. Further, a deep tech fund was announced in Union Budget 2025 to encourage youngsters of the country to develop more startups by converting their dream ideas into developed ventures [5]. Government also initiated National Geospatial Mission (NGM) with funding of Rs 100 crore for 2025-26. The aim of NGM is to develop better geospatial infrastructure, and it will be further funded under the Pradhan Mantri Gati Shakti [5]. NGM will help modernize land records and e- records and improve urban regions and infrastructure. It will help improve climate planning and city design through Geographical Information Systems (GIS).

The government also initiated several policies to address climate change issue. Some of the people are adopting a carrot approach, with green taxes on activities affecting the environment. Electronic Vehicle (EV) is a additional tool that increase demand of green products and services like solar panel or renewable energy. Along with, such tools and tax rebates, Government also started various funding and subsidies for research institutions to increase research in renewable energy, waste management, and energy efficiency domain. Thus, Government-led initiatives not only help society but also help establish the bridge between science, society, and sustainability.

Categorization of Departments/ Government Organization based on funding agenda

India has various departments and organization which provide funding for the initiatives taken by the Department at national and international level. The list of departments and organization which provide funding in various fields to support research and development for inclusion of science to solve societal problems. The funding bodies to promote scientific research include:

- DST: It supports funding through NIDHI, NM-ICPS, SERB [1].
- SERB: It supports funding for basic and applied research in science and engineering such as, Core Research Grant (CRG), Start-up Research Grant (SRG), and various initiatives for early-career and women scientists, such as the National Postdoctoral Fellowship (N-PDF) and the POWER program. Further, SERB also supports collaborative work between academia and industry through various programs such as Fund for Industrial Research Engagement (FIRE).
- India Science, Technology and Innovation (ISTI) Policy Secretariat: It supports research through STI policy and mission-mode initiatives [4].
- Council of Scientific and Industrial Research (CSIR): It supports research in environment, health, water, and energy [7].

Environment & Sustainability-Oriented Agencies

- Ministry of Environment, Forest and Climate Change (MoEFCC): Supports research through National Adaptation Fund for Climate Change (NAFCC), Green India Mission [3].
- National Biodiversity Authority (NBA): Supports usages of sustainable and biodiversity conservation.
- Indian Council of Forestry Research and Education (ICFRE): Supports forestry research with societal applications.

Society and Health-Driven Institutions

- Indian Council of Social Science Research (ICSSR): Supports research in social sciences impacting policy.
- Indian Council of Medical Research (ICMR): Supports health research focused on community welfare and public health.
- National Innovation Foundation (NIF): Supports grassroots innovators, especially in rural communities.

Technology, Rural & Innovation

- Ministry of Electronics and IT (MeitY): Supports digital inclusion, sustainability in ICT [8].
- National Institution for Transforming India (NITI Aayog): Think tank guiding policies for SDGs and socio-economic development.
- Ministry of Rural Development (MoRD): Support rural sustainability and livelihoods.
- Technology Development Board (TDB): Support financial assistance for technology commercialization.

India's path to sustainable development is closely linked to scientific advancement and its application in society. The government has actively started a number of programs to promote community growth, innovation, and environmental responsibility. The alignment of science with the needs of society and the goals of sustainability, India is paving the way for an eco-friendly future. With continued policy support, community participation, and scientific quality, India can emerge as a global leader in sustainable innovation. Government is continuously working to start effective schemes for Viksit Bharat 2047 and Agenda 2030 in order to provides accessibility to every citizen

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Bilateral collaboration on experimental and computational calculations study of non-covalent interactions to structure-properties elucidation

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Abstract

Here is reported the interdisciplinary collaboration between the Polymers Group at BUAP and the DBT Biomolecular Crystallography Laboratory and Bioinformatics Center group at SASTRA Deemed University, which has evolved into a mature and productive partnership based on computational and physicochemical-experimental expertise. Initially focused on exploring molecular structures shared by the Polymers Group, the collaboration has progressed to develop cases of studies involving conjugated compounds, with a focus on quantifying and visualizing non-covalent interactions. This has led to joint supervision of postgraduate researchers, reciprocal short laboratory visits, and the establishment of regular working sessions. Currently, members of the research group co-authoring numerous research papers, have manuscripts under preparation, and are serving as co-editors in the Frontiers in Chemistry journal. They were also awarded the INDO-G20 faculty 2023-2024 SASTRA Deemed University. Here, mainly reported are the details of a study that presents a combined experimental and theoretical analysis, spectroscopic characterization, and non-covalent interactions (NCIs) for a class of compounds, such as conjugated and medicinally important adamantane derivatives, including spectroscopic analysis and DFT-based interaction energy calculations.

Introduction

The non-covalent interactions, such as intra- and intermolecular interactions, play a significant role in determining the chosen substance's chemical, physical, electronic, and biological properties. The conventional non-covalent interactions, such as N-H…O and N-H…N hydrogen bonds, have been well recognized in different biological systems, including proteins and nucleic acids. However, unconventional interactions could also be essential in determining the substance's physical, chemical, and biological properties. Several unconventional weak interactions have been identified, and their role in various systems is studied. Among the various unconventional interactions, σ-hole interactions play a vital role in controlling supramolecular self-association in the solid state, thereby determining optical properties. The investigation of the physicochemical properties of π-conjugated organic compounds has garnered significant attention in the field of solid-state physics, primarily due to their applications in optoelectronics.

The crystal molecular structure is determined by intramolecular and intermolecular forces, as well as the quantification of lattice energy, to understand the crystallization process. Therefore, knowledge of intermolecular forces and their orientations is a prerequisite for understanding the structure-property relationships of molecular crystals. Therefore, knowledge of intermolecular forces and their orientations is an essential prerequisite for understanding the structure-property relationships of molecular crystals. We have reported a significant number of conjugated organic crystals to evaluate the effect of substituents on optoelectronic properties, such as charge transfer between an electron donor (D) and an electron acceptor (A). To understand the properties of supramolecular systems, computational modeling is applied to evaluate non-covalent interactions from a point of view of experimental spectroscopy and computational approaches.

Experimental and chemical calculations approach

To gain a deep understanding of the structural-properties relationship in advance functional materials, it is essential to integrate both experimental and computational methodologies. These complementary approaches are crucial for characterizing spectroscopic features and solid-state properties, particularly through the analysis of non-covalent interactions (NCIs). From an experimental perspective, a variety of spectroscopic and analytical techniques, such as infrared (IR), nuclear magnetic resonance (NMR), UV-Vis, fluorescence spectroscopy, scanning electron microscopy (SEM), transmission electron microscopy (TEM), and powder X-ray diffraction (PXRD) are routinely employed to characterize novel functional materials. Among these, single-crystal X-ray diffraction (SCXRD) plays a pivotal role in unveiling the intermolecular and intramolecular NCIs that govern crystal packing and supramolecular organization. However, experimental techniques often face limitations when it comes to quantifying weak NCIs, such as π-π stacking, C-H π interactions, halogen bonding, and other non-classical interactions. Furthermore, solvent effects which can significantly influence the behavior of materials in the solution phase, are difficult to isolate or quantify through experimental methods alone. These challenges underscore the necessity for computational support to complement and enhance experimental findings.

To this end, computational methods based on the density functional theory (DFT) and wavefunction-based approaches (e.g., MP2, CCSD(T)) are extensively employed to calculate NCIs energies, electron density distributions, and molecular orbitals. Tools such as CLP-PIXEL, NCI index plots, reduced density gradient (RDG) analysis and the electron localization function (ELF) provide insightful visualizations and interpretations of NCIs. Additionally, energy decomposition analysis (EDA) allows for the breakdown of interactions energies into key components such as electrostatics, dispersion, and polarization. To simulate solvent effects and NCIs behaviors in bulk systems, quantum mechanics/molecular mechanics (QM/MM) methods and molecular dynamics (MD) simulations are increasingly applied. Widely used computational tools in this domain include AIMAll, Multiwfn, CrystalExplorer, Gaussian, ORCA, CRYSTAL.

The success of computational studies lies in their ability to complement experimental observations, offering atomic-level insights into non-covalent interactions (NCIs). While experimental techniques provide observable data such as IR, UV-Vis, NMR, fluorescence, and crystal packing, and computational methods uncover the underlying energetic and electronic origins. Together, they form a powerful, integrated framework for understanding NCIs and guiding the rational design of functional materials.

Collaboration impact

Experimental-computational groups create a synergy that is innovative in advanced materials research. In Mexico, the polymers group has experience in the synthesis, characterization, and applications of styrylpyridines, dipehnylamino-, acrylonitrile, imidazole, fluorene, and chalcone derivatives, which exhibit excellent optical, electrical, and photophysical properties for applications in OLEDs and Solar cells with acceptable performance. Therefore, structural studies and characterization of these compounds are essential for correlating their structural and optical properties. In India, Dr. Thamotharan's group has employed various computational methods to characterize noncovalent interactions both qualitatively and quantitatively, investigating the crystal topology and optical properties under different conditions. Additionally, an essential synergy of collaboration is the interdisciplinary training of students, which is necessary for progress in synthesis strategies and the application of materials science.

Herein, 2-styrylpyridine is presented as a model compound to show the significance of combining experimental and computational approaches in understanding its structural, electronic, and solid-state properties. The first is the molecular structure optimized in the gas phase, followed by vibrational frequency calculations using DFT at the B3LYP/6-311+G(d,p) level of theory in the Gaussian 16 program (Frisch M. J. et al., 2009; McKinnon et al., 2007). The optimized structure is compared with the experimental crystal structure, and it is in good agreement based on the RMSD. In Fig. 1, the molecular structures are shown overlaid, with a slight difference in the pyridine ring. A computed FT-IR spectrum of 2-styrylpyridine is demonstrated on Fig. 2, and 69 normal vibrational modes were observed. The unscaled B3LYP/6-311+G(d,p) calculated vibrational frequencies are generally higher than the corresponding experimental values. To improve the agreement between theory and experiment, a scaling factor of 0.966 was applied to the computed frequencies.

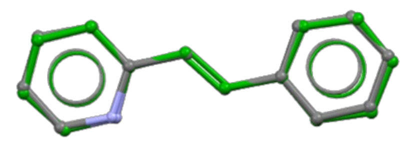

Fig.1. Structural superimposition of crystal structure (carbon atoms in elemental colour) and optimized molecule (carbon atoms in green colour). The oxygen and nitrogen atoms in elemental colour in both structures.

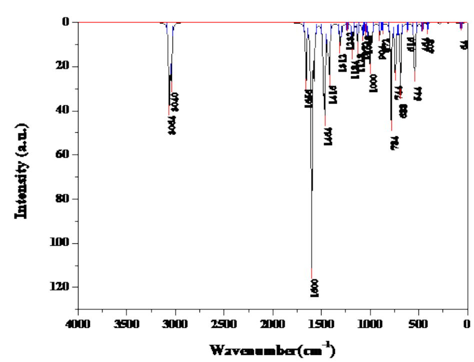

Fig. 2. The computed FT-IR spectra of 2-styrylpyridine at B3LYP/6-311+G(d,p) level of theory.

UV-Vis & HOMO-LUMO

To investigate the electronic properties 2-styrylpyridine, its UV-Vis absorption spectrum was computed, as shown in Fig. 3 (A). The calculated λ_{max} value is 290 nm in the gas phase, with oscillator strengths of 0.84 a.u. This absorption is predominantly associated with the HOMO→LUMO transition contributing 96 % and corresponds to the $S_0 \rightarrow S_1$ electronic excitation. The calculated Frontier Molecular Orbitals (FMOs) are illustrated in Fig. 3 (B). The electron density in both HOMO and LUMO is delocalized over the entire molecular framework, and differences in the delocalized electron density indicating an intermolecular charge transfer character in 2-styrylpyridine.

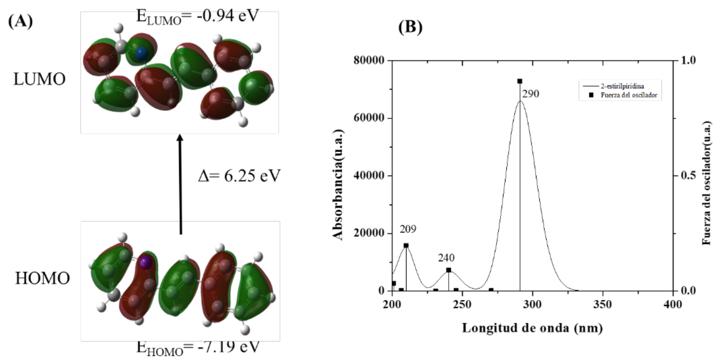

Fig. 3. (A) Localization of HOMO and LUMO molecular orbitals, (B) The computed UV-Vis absorption spectra of 2-styrylpyridine.

Qualitative analysis of intermolecular interactions

The intermolecular interaction energies (*Etot*) of various dimeric pairs in the crystal structure of 2-styrylpyridine were calculated using the CLP–PIXEL program. This analysis identified five key dimeric motifs (D1–D5) extracted from the crystal packing. The calculated interaction energies ranged from –5.2 kcal/mol to –2.2 kcal/mol, indicating weak to moderate non-covalent stabilization. Representative examples of dimers D1 and D2 are illustrated in Fig. 4(A). To qualitatively analyses the intermolecular interaction, present in the crystal, Hirshfeld surface (HS) analysis and corresponding 2D fingerprint plots (2D-FP) were performed. The HS mapped over dnorm (Fig. 4B) reveals prominent bright red spots, which correspond to significant close contacts between molecular fragments. These contacts are mainly due to π–π stacking interactions, further confirmed by the shape index (SI) diagram shown in Fig. 4(D).The 2D fingerprint plots (Fig. 4C) display the frequency and contribution of various intermolecular contacts, notably H···H, H···C/C···H, H···N/N···H, and C···C interactions, all of which play important roles in the crystal packing of 2-styrylpyridine. Overall, the combined insights from CLP-PIXEL calculations and Hirshfeld surface analysis highlight the diversity and significance of non-covalent interactions governing the supramolecular architecture of 2-styrylpyridine.

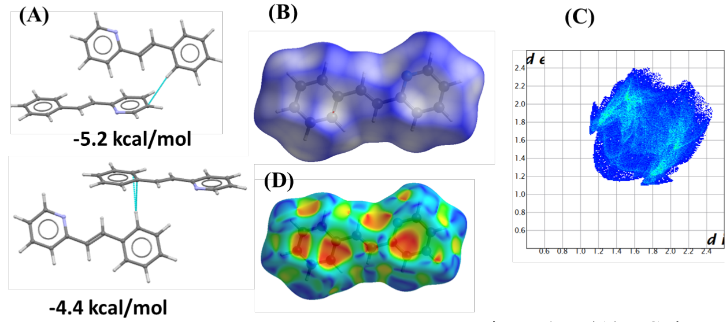

Fig. 4. (A) Selected molecular pairs (D1 and D2) with interaction energies extracted from the crystal packing. (B) Hirshfeld surface (HS) mapped with d_{norm}; (D) shape index (SI) map. (D). Two-dimensional fingerprint (FP) plots of 2-styrylpyridine

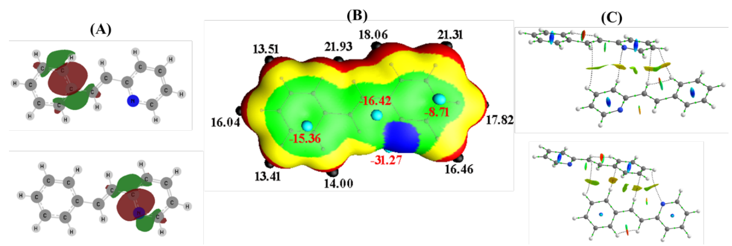

Fig. 5. (A) Natural bond orbitals (NBO) showing the intermolecular charge transfer behaviors. (B) Molecular electrostatic surface potential of the 2-styrylpyridine is mapped over the electron density isosurface at 0.001 a.u. The positive (Vs, Max) and negative (Vs. min) potentials are labeled. (C) The (3, -1) bond critical points (BCPs) for intermolecular noncovalent interactions analysis via QTAIM approach.

Since the collaboration between the polymer group and the DBT Biomolecular Crystallography Laboratory and Bioinformatics Center group began, the synergy has led to 60 articles published in high-impact journals, two of which have been chosen as cover illustrations for the journal issue where published, Fig. 6, and are co-edited by Frontiers in Chemistry, with the NCIs issue in 2023 and 2025 (Co-Edited by Frontiers in Chemistry). Professor Dr. Thamotharan received recognition from the G20 program in 2023. In addition, the University of SASTRA and BUAP signed a Memorandum of Understanding to strengthen the scientific research of both universities and promote the exchange of high-level students and teachers, as well as collaboration in research projects and professional development, among other academic activities. An important part of the collaboration has been the impact on students regarding knowledge acquired on computational calculations given through talks and workshops carried out during the visits. Participation in teaching through the creation of online courses using computational and experimental calculations at the laboratory level for the knowledge of fluorescence of organic materials: "MOOC: Luminescence: the light of nature," bringing together science and art students at BUAP

(A) research communications

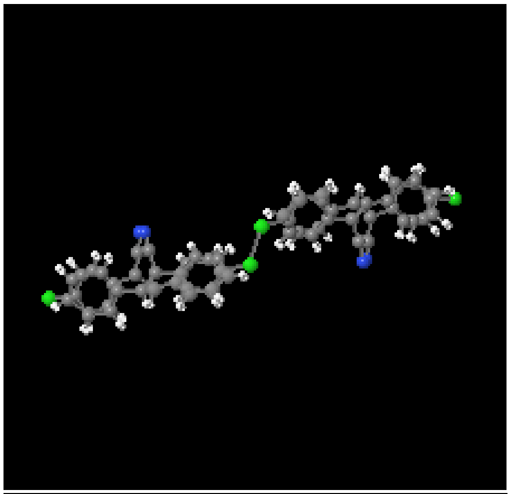

Fig. 6. (A) Acta Cryst. (2019) E75,499-505, 10.1107/S2056989019003694 Cover illustration: The crystal and molecular structures of (Z)-3-(4-chlorophenyl)-2-phenylacrylonitrile are reported and the weak non-covalent interactions present in the crystal structure have been investigated. (B) Cover illustration: Film morphology of acrylonitrile materials deposited by a solution process and vacuum evaporation. Supramolecular interactions, optoelectronic properties and approximation by computational calculations (Pérez-Gutiérrez et al., 2019).

Fig.6 B NJC

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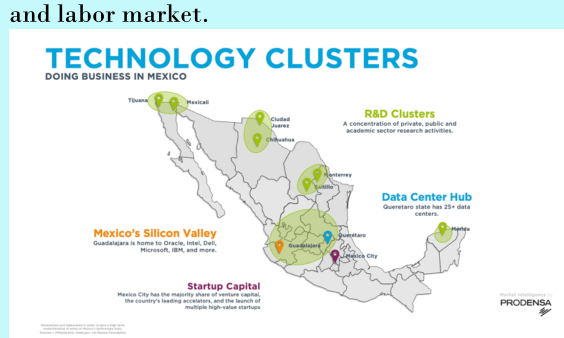
Science and Technology Development in Mexico

Mexico is developing its science and technology sector, particularly in Information and Communication Technologies (ICT), automation, and biotechnology, with key hubs in Mexico City, Guadalajara, and Monterrey driving innovation. The government focuses on digital infrastructure, skills training, and fostering private-public partnerships to boost tech capacity and address social/environmental issues. Challenges remain, including limited funding for science and disparities between highly skilled professionals and low-productivity jobs. Mexico is leveraging its skilled workforce and favorable trade environment for nearshoring to become a regional leader in IT outsourcing, software development, and digital commerce, supported by broadband expansion and digital skills training initiative. A growing focus on this sector includes developing new technologies for health and agriculture, with examples like antivenoms and other innovations emerging from research institutions. The states of Guanajuato and Querétaro are emerging as significant R&D centers for these industries, building on their strategic locations and infrastructure. The government is actively partnering with the private sector and academia to invest in technology development and innovation. Efforts are underway to bridge the tech skills gap, with ambitious programs aiming to train millions in digital skills to support the workforce and labor market.



Source: Prudensa Mexico

SYNERGY: A Data-Driven Smart Home Energy Optimization System for Sustainable Living

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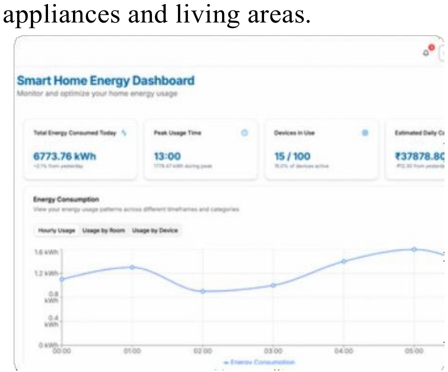
Introduction

Energy inefficiency in modern homes often stems from unnoticed behaviors—air conditioners running in unoccupied rooms, lights left on for extended periods, and appliances operating without purpose. Though individually minor, these instances collectively lead to increased energy expenses, resource depletion, and environmental degradation. Earlier smart home systems attempted to address such issues through basic automation but relied heavily on fixed schedules or simplistic triggers, lacking contextual awareness. SYNERGY, an advanced Smart Home Energy Optimization System, bridges this gap by introducing adaptive, data-driven intelligence that transforms conventional energy management into a smarter, more efficient process.

Features and Functionality

SYNERGY revolutionizes home energy usage by infusing real-time learning, predictive analytics, and adaptive decision- making into its very fabric. The system combines a distributed network of IoT sensors deployed on key appliances and living areas.



These sensors continuously gather data on device-level energy usage, environmental conditions like temperature and humidity, and occupancy patterns around the home. This dense dataset creates a dynamic, detailed digital model of the home's energy profile, systematically stored in a MySQL database. Three expert machine learning models lie at the heart of SYNERGY's intelligence:

- **Energy Consumption Forecasting:** A predictive model estimates the energy usage of individual devices in the near future based on historical patterns. This enables proactive management of appliances, such as preemptively powering down systems before unnecessary consumption occurs.
- **Peak Usage Detection and Load Balancing:** By analyzing temporal trends, SYNERGY identifies periods of peak energy consumption. The system offers strategic load balancing recommendations, an especially valuable feature for homes equipped with smart meters or renewable energy sources like solar panels, where shifting demand can reduce both operational costs and carbon footprints.
- **Anomaly Detection for Inefficiency Identification:** Advanced anomaly detection algorithms, including Isolation Forests, continuously monitor system behavior. Irregularities such as a refrigerator drawing abnormal levels of power or a heater operating during summer are swiftly flagged, allowing for either automated corrective action or user alerts. SYNERGY emphasizes not just responding to conditions but actively anticipating and optimizing them, aligning energy usage more closely with actual human activity and environmental context.

Recommendation System for Smart Energy Optimization: An advanced, AI- driven recommendation system that seamlessly integrates with large language models like Gemini to deliver intelligent, context-aware suggestions for optimizing energy usage. Unlike traditional systems that offer static commands such as “turn off this appliance,” this model analyses a variety of dynamic inputs-including environmental conditions, user preferences, occupancy, and device behavior-to generate relevant, actionable recommendations. Whether it’s rescheduling high-consumption appliances or fine-tuning settings based on real-time data, the system ensures each recommendation is personalized (Aggarwal, 2017), meaningful, and energy- efficient.

Technical Implementation

SYNERGY’s architecture is built for real- time responsiveness, modularity, and production reliability. IoT sensor data streams continuously into a central Mysql (Date, 2015) database, where the backend retrieves, preprocesses, and analyses it. Machine learning models, developed with Scikit- learn and XGBoost (Chen & Guestrin, 2016) and serialized using Joblib, ensure consistency between training and live environments. RESTful APIs enable seamless communication between the database, ML pipelines (Breiman, 2001), and the Next.js-based frontend, which provides intuitive, real-time visualizations of energy trends, device insights, and system recommendations.

Scalability and Future Enhancement

SYNERGY is designed with flexibility at its core, built to scale effortlessly across diverse home settings—from small studio apartments to expansive multi-level smart homes. Its modular architecture makes it easy to expand, whether by adding new rooms, connecting more appliances, or integrating advanced machine learning models—all without disruption or downtime. Looking ahead, SYNERGY aims to make smart energy management even more intuitive through Natural Language Processing (NLP), paving the way for seamless, voice-driven interactions that make controlling your home as simple as having a conversation.

With this advancement, users will be able to interact with SYNERGY in a natural, conversational way—giving intuitive commands like, "Turn off the heater if the room is empty for over 30 minutes," or "Run the washing machine only during off- peak hours." By combining conversational AI with real-time context awareness, energy management becomes not only smarter but also remarkably easy to use.

Looking ahead, SYNERGY's roadmap includes powerful new capabilities such as:

- Multi-language support to enhance accessibility for diverse households
- Goal-based optimization, like "Reduce my energy bill by 20% this month"
- Seamless integration with smart assistants like Alexa, Google Home, and more

Conclusion

With energy demands steadily rising, modern homes need more than just basic automation. SYNERGY represents a new era of smart energy management—one that uses real-time data, predictive insights, and adaptive learning to make homes more efficient and sustainable. Instead of simply reacting to changes, SYNERGY anticipates them, making intelligent, context-aware decisions that reduce waste and improve comfort. It's a step toward living environments that aren't just smart, but truly in sync with how we live and use energy.

Acknowledgement

We would like to sincerely thank Prof. Dinesh Kumar Vishwakarma, HOD, Department of Information Technology, for always providing us with the appropriate platform to showcase our potential. We also thank the administration of Delhi Technological University for their invaluable guidance and support throughout this project. We are especially grateful for the encouragement and mentorship that helped shape our ideas and efforts. Their belief in our work has been a constant source of motivation.

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India's biotechnology sector has emerged as sunrise industry with significant growth potential, valued at $80 billion as of 2022. This sector has diverse potential, with strong focus in the areas including biopharmaceuticals, bio-agriculture, bioinformatics, bio-fashion, and industrial biotechnology. The government actively supports the growth of this sector through entities like the Department of Biotechnology (DBT) and the proposed Biotechnology Regulatory Authority of India. Major biotechnology firms in India-View here

Innovations in Biotechnology Using Artificial Intelligence: A Decade of Transformative Advances

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1. Introduction

Over the past decade, artificial intelligence (AI) played an important role in biotechnology, it brought various changes in biological research. With the help of machine learning and deep learning, AI plays an important role in handling large and complex biological data, which helps in capturing new insights, especially in areas where earlier methods were slow or limited.

AI influenced various aspects of biological problems like problem understanding and solving. Earlier, analysing tasks like gene sequences, protein structures, or even high-resolution cell images require a lot of time and need manual and step by step procedures. These tasks were often repetitive and prone to human error. Now, AI helps to do the same work more quickly and with greater accuracy. It reduces the burden of routine tasks and helps in identifying patterns in data that may not be easily visible otherwise. Because of this, fields like genomics, molecular biology, and drug discovery are seeing faster progress and better outcomes.

Recently, researchers are explornig biological areas that are previously considered too complex or time-consuming. They are building new biomolecules, studying gene-protein interactions, and even predicting how cells might behave if certain genes are changed. AI is also helping in personalized medicine, where treatment is planned according to a person's genetic profile and medical condition. This not only saves time but also increases the chances of better results in patient care.

In India and Mexico, research institutions are actively exploring the applications of AI in health and other domains

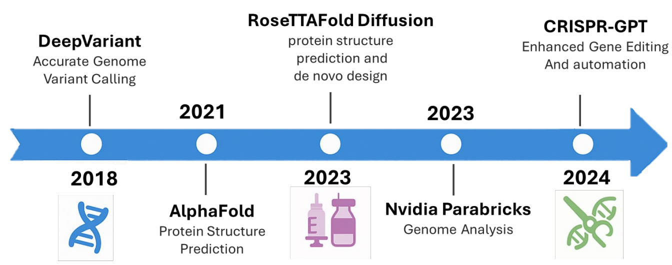
with biotechnology. Both India and Mexico face similar challenges in public health and sustainable agriculture, making AI-driven biotechnology a natural area for research collaboration. Joint initiatives, academic partnerships, and technology exchange between the two countries can lead to innovative and context-sensitive solutions for shared socio-economic priorities.

2. AI-innovations in Biotechnology

AI and biotechnology integration has totally changed modern biological research, which has created a symbiotic relationship between computational and experimental discovery. At the forefront of this shift, tools like DeepVariant show how deep learning transforms raw genomic data into clinical insights. By automating variant detection with 99.7% SNP concordance in whole-genome analyses. This technology has reduced 60% sequencing costs while reducing the diagnostic timelines from months to days (Poplin et al., 2018; Zhou et al., 2019).

The genomic revolution gave one of biotechnology's most pivotal breakthroughs: DeepMind's AlphaFold. In 2020, AlphaFold cracked the 50-year protein folding challenge with atomic precision, achieving a backbone accuracy of 0.96Å RMSD (Jumper et al., 2021). AlphaFold's transformer architecture slashed computational costs for binding site identification by 75%, enabling researchers to virtually screen

Fig 1. Timeline of AI -driven innovations in Biotechnology



100 million compound libraries in weeks rather than years (Bouatta, Sorger, & AlQuraishi, 2021). During the COVID-19 pandemic, this capability proved lifesaving. Ensemble models combined AlphaFold-predicted viral protein structures with docking simulations to identify baricitinib-a rheumatoid arthritis drug-as a repurposed therapeutic, bypassing years of traditional trial-and-error (Liu et al., 2022).

IBM Watson analyzes complex genomic datasets faster than human experts, validated in glioblastoma studies where it identified actionable mutations in 10 minutes versus

160 hours of manual curation (Wrzeszczynski et al., 2017). While Watson achieves 89.8% similarity with multidisciplinary tumor boards in variant classification (Itahashi et al., 2018), its true value lies in bridging the gap between data overload and clinical decision-making. As in metastatic breast cancer cases, Watson's recommendations align with oncologists' choices only 45% of the time, underscoring the need for human-AI collaboration in complex scenarios ("How Watson for Oncology Is Advancing Personalized Patient Care - The ASCO Post," n.d.). Exscientia's DSP-1181, the first AI-generated drug candidate for obsessive-compulsive disorder, entered Phase II trials in 2023 (Burki, 2020).

Evogene's collaboration with Google Cloud marks a transformative leap in generative AI for small molecule design, leveraging Vertex AI and high-performance computing to train a foundation model on ~40 billion molecular structures ("Evogene Announces Collaboration with Google Cloud to Pioneer Generative AI Foundation Model for Novel Small Molecule Design – Evogene," n.d.; "Evogene Case Study | Google Cloud," n.d.).

This partnership enables ChemPass AI-Evogene's computational engine to design novel molecules with precision. The platform integrates deep learning and predictive biology, streamlining de novo molecular generation while balancing parameters like binding affinity and synthetic feasibility.

NVIDIA Parabricks revolutionizes genomic analysis by leveraging GPU acceleration to reduce processing times. This scalable suite accelerates industry-standard tools like GATK HaplotypeCaller and DeepVariant, achieving up to 65× faster germline variant calling, reducing a 36-hour workflow to just 24 minutes on NVIDIA DGX systems (O'Connell et al., 2023). Parabricks' cloud integration with AWS and GCP reduces costs by 40–60% for germline workflows, though somatic analyses face scalability challenges due to GPU underutilization. Parabricks bridges the gap between data generation and actionable insights-propelling advancements in precision medicine, infectious disease tracking, and agricultural genomics while navigating technical and economic hurdles.

RoseTTAFold Diffusion (RFdiffusion) merges deep learning and diffusion models to revolutionize protein design, enabling de novo creation of functional proteins with atomic precision ("RFdiffusion: A Generative Model for Protein Design Baker Lab," n.d.). By fine-tuning the RoseTTAFold structure prediction network, RFdiffusion generates diverse protein backbones tailored to user specifications-from high-affinity binders to symmetric assemblies and enzyme scaffolds. Demonstrating remarkable efficiency, RFdiffusion designs a 100-residue protein in ~11 seconds on consumer GPUs, achieving >50% experimental success rates for symmetric nanomaterials and metal-binding proteins.

3. Potential Breakthroughs

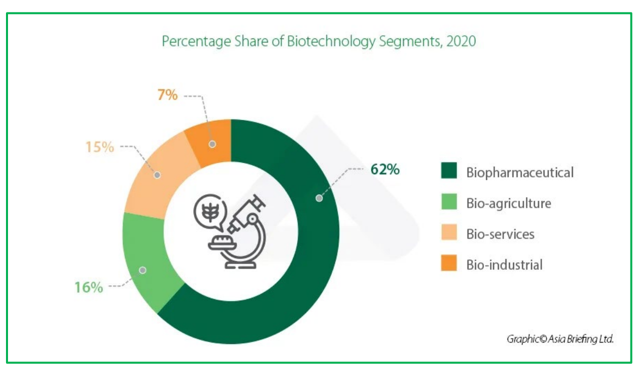
There are various emerging potential breakthroughs which are and will shape the future of Biotechnology. Platforms like CRISPR-GPT (Huang et al., 2024), are one of them which leverage large language models (LLMs) to automate gene-editing experiments, optimizing CRISPR-Cas9 designs for precision and scalability. Future applications include microbial consortia engineered for carbon capture and algae modified for heavy metal bioremediation. Such systems could revolutionize environmental management and sustainable manufacturing. AI is refining cell and gene therapies by predicting off-target effects and optimizing delivery vectors. For example, WhiteLab Genomics uses machine learning to design adeno-associated virus (AAV) ("Sanofi, WhiteLab Genomics, the TaRGeT Laboratory at Nantes University, and Institut Imagine Launch WIDGeT to Make France a Global Leader in Gene Therapy. Institut Imagine," n.d.) capsids with enhanced tissue specificity, reducing immune responses in clinical trials. Future platforms may tailor CAR-T cell therapies to individual tumor profiles, minimizing cytokine release syndrome risks. The intersection of quantum computing and AI (quantum machine learning, QML) is unlocking new frontiers in molecular simulation and drug discovery (Raju, Quazi, & Kondle, 2024). Quantum algorithms excel at modeling molecular interactions in large configuration spaces, enabling precise simulations of protein folding or ligand-receptor binding. Quantum-enhanced image analysis also shows promise in detecting early-stage cancers from medical scans, improving diagnostic accuracy by 25%. Digital twin computational models make virtual replicas of biological systems or processes which optimize biomanufacturing and therapeutic development (Casola, 2023). In production, they simulate bioreactor conditions in real time, predicting optimal nutrient feeds and reducing batch failures by 40%.

4. Challenges

This paradigm shift is not without challenges. Issues of data quality, model interpretability, and ethical considerations-

such as privacy, bias, and dual-use risks-remain as significant challenges. Black-box AI systems, such as deep neural networks, hinder clinical adoption due to a lack of transparency. For instance, AI tools predicting drug toxicity often fail to explain *why* a compound is flagged, complicating regulatory approval. Techniques like SHAP (SHapley Additive exPlanations) are being integrated to quantify feature importance, but further work is needed to align AI outputs with mechanistic biology. AI lowers barriers to harmful applications, such as designing pathogens.

Nevertheless, the integration is moving research from hypothesis-driven to data-driven and hypothesis-generating methodologies, amplifying human creativity and insight rather than replacing them. As experts like Professor Aviv Regev and Dr. Jeantine Lunshof have noted, AI has become an indispensable partner in biotechnology, handling the complexity of biological data and highlighting the most promising directions for scientific discovery.



Conclusion

Over the past decade, artificial intelligence has become a key part of biotechnology. Tools like AlphaFold made the understanding of proteins fold easier. AI is also helping in the discovery of new drugs and improve gene editing through CRISPR-based methods. Such developments are changing the biological research and opening up new innovative areas. However, the important challenges about ethics, data privacy, fairness in access to technology, and the need for reliable infrastructure must be addressed. These problems require cooperation, shared learning, and trust between nations. The future of biotechnology is not only dependent on advanced machines or faster algorithms - it is dependent on how responsibly and inclusively the methods are used.

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Enhancing Research Opportunities and Partnerships at Delhi Technological University Through a Dedicated Web Application - DTU Research Connect

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This work examines a novel web application designed to foster research collaboration between students and professors in Delhi

Technological University (DTU), aiming to elevate the institution's research output and quality. By analyzing the existing research ecosystem at DTU and drawing insights from successful research collaboration platforms, it highlights the key features and potential benefits of the application in facilitating problem-solving and research partnerships. The application's role in empowering student-student collaboration, bridging the gap between students and professors, and its scalability for adoption by other universities are also discussed.

Introduction:

Research is fundamental to higher education, driving innovation and enhancing institutional reputation. Collaborative efforts between students and faculty are particularly valuable in enriching the research environment. This paper introduces a web application developed to serve as a central resource hub at (DTU), facilitating seamless interaction and collaboration among students and professors to enhance the overall research landscape.

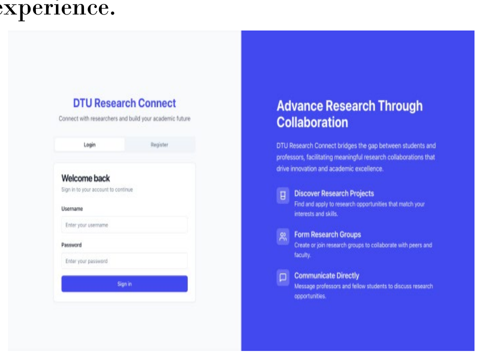
Current Research Ecosystem at Delhi Technological University

DTU boasts a strong research culture across science, technology, engineering, and management. The university actively engages in international collaborations and maintains close ties with national R&D centers. Students have various avenues for research engagement, including postgraduate projects, summer internships, and undergraduate research courses. While DTU offers a vibrant research environment, a centralized platform to facilitate the formation of research partnerships based on shared interests and skills is currently lacking.

Web Application Features and Functionalities for Research Advancement

The developed web application aims to address the gap in DTU's research ecosystem by providing specific features that facilitate connections based on academic interests, skills, and research goals. Key functionalities include:

Faculty Research Project Listings: Professors can post detailed descriptions of available research projects, outlining the scope, required skills, and time commitment.
Student Profiles: Students can create comprehensive profiles detailing their research interests, technical skills, and prior experience.



Peer Collaboration Tools: Features enable students to search for peers with complementary skills or shared research interests and form student- led research teams.
Project Idea Posting: Students can post their own research project ideas and invite other students to join.
Private Research Groups: The platform allows for the creation of private group spaces with communication and resource-sharing tools.

The web application also empowers student-student partnerships by providing tools for connection[1] based on shared academic pursuits and complementary skills. Detailed student profiles allow for targeted searches for collaborators. Students can post their research project ideas, outlining required skills and inviting peers to join. Private research groups within the platform offer communication and resource-sharing functionalities, streamlining peer-led research initiatives.

Bridging the Gap Between Students and Professors

The application facilitates connections (Shee et al., 2010) between students and professors by enabling professors to post available research projects with comprehensive details. Students can easily discover these opportunities through a centralized platform and apply via a standardized interface. Integrated messaging tools streamline communication between students and professors, fostering greater engagement in faculty-led research

Anticipated Impact on Research Engagement and Output at DTU

The web application is expected to significantly enhance student involvement (Wegner et al., 2024) in research and boost DTU's overall research productivity. By centralizing opportunities and facilitating collaborations, the platform can lower barriers to research engagement for students and lead to more efficient and effective research teams. Increased visibility for research activities may also encourage greater participation and recognition within the university community.

Scalability and Adaptability for Other Universities

The web application's potential (Naik, 2023) for adoption by other universities depends on its scalability and adaptability. A modular, cloud-based architecture would enhance scalability and ease of customization for different institutional environments. Seamless integration with existing university systems and cost-effectiveness will also be crucial factors for wider adoption.

Potential Benefits for Students at Other Universities

Students at other universities adopting this web application could experience increased access(*(PDF) Digital Project Repository: A Community for Students to Collaborate Research Projects*, n.d.) to research opportunities, facilitated collaborations with peers and faculty, and enhanced engagement in research activities. This can lead to improved research skills, critical thinking abilities, and overall academic preparedness (Research Ecosystem within Indian Higher-Education Sector | EY - India, n.d.), ultimately enhancing their academic and career prospects.

Conclusion

The web application developed for DTU holds significant potential to transform the university's research landscape by fostering collaboration and enhancing research opportunities for students and faculty. Its scalability suggests a broader applicability across higher education institutions. Strategic implementation and continuous improvement based on user feedback will be key to realizing its full potential.

Acknowledgement

We would like to sincerely thank Prof. Dinesh Kumar Vishwakarma, HOD, Department of Information Technology, for always providing us with the appropriate platform to showcase our potential. We also thank the administration of Delhi Technological University for their invaluable guidance and support throughout this project. We are especially grateful for the encouragement and mentorship that helped shape our ideas and efforts. Their belief in our work has been a constant source of motivation.

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Sustainability Programs in India

Sustainability programs in India range from national-level flagship initiatives like Mission LiFE and the Green Hydrogen Mission to educational programs offered by institutions like Nalanda University, IIM Mumbai, and the TERI School of Advanced Studies, focusing on areas such as environmental conservation, clean energy, poverty alleviation, and sustainable development. Non-governmental organizations (NGOs) and think tanks also contribute through community-focused programs and policy research.

The concept of 'Lifestyle for the Environment (LiFE) was introduced by Prime Minister Narendra Modi at COP26 in Glasgow on 1st November 2021, calling upon the global community of individuals and institutions to drive LiFE as an international mass movement towards "mindful and deliberate utilization, instead of mindless and destructive consumption" to protect and preserve the environment. LiFE puts individual and collective duty on everyone to live a life that is in tune with Earth and does not harm it. Those who practice such a lifestyle are recognized as Pro Planet People under LiFE.

Changing our lifestyle, however, is not easy. Our habits are deeply ingrained in our daily lives and are continually reinforced through several elements of our environment. Translating our intention to do good for the environment is not always easy to translate into action. However, it is not impossible. By taking one action at a time and making one change daily, we can change our lifestyle and inculcate long-term environment-friendly habits. Studies suggest that practicing an action for a minimum of 21 days helps make it a habit.

In that context, the LiFE 21-Day Challenge is launched to enable Indians to take one simple environment-friendly action per day for 21 days and eventually develop an environment-friendly lifestyle. It is a challenge to change one small thing in your life daily and become Pro Planet People.

Changing individual and community behavior alone can make a significant dent in the environmental and climate crises. According to the United Nations Environment Programme (UNEP), if one billion people out of the global population of eight billion adopt environmentally friendly behaviors in their daily lives, global carbon emissions could drop by approximately 20 per cent

Source: https://www.mygov.in/life/ Government of India

Generative Artificial Intelligence and Societal Well-Being: Is it Possible?

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What is artificial intelligence?

We have been using artificial intelligence in our daily lives for a long time. Artificial intelligence is a computer program that, in its beginnings, helped to make the operation of companies more efficient, for example, by reducing the time it takes to find the optimal route between two points. We experience this every day when we ask for an Uber service, and where the digital map is handy in identifying the best way to reach our destination, whether our criteria are the shortest route in kilometres or time, or the one that represents the lowest fuel cost. Another example that is quite common today is the filters used by photo or video applications on social networks. In this case, if we want to use rabbit ears, we select the filter from a menu, and those rabbit ears will follow the movements of our face when recording a video clip. This example may sound trivial, but it is a fun application of artificial intelligence. Whether we like rock, blues, or regional music, an artificial intelligence algorithm remembers these musical preferences, searches its database for other similar songs, and recommends more songs according to those preferences.

Without realising it, every day we use applications that are already designed according to algorithms that optimise many activities in our daily lives. Artificial intelligence applications grew exponentially about two years ago, when the technology company OpenAI launched software based on large language models that can process people's natural language, i.e., how we speak daily. They called this tool chatGPT.

The artificial intelligence algorithms that use the chatGPT chat are trained using publicly available Internet content and everything we write, post, and upload to social networks. The answers we read when we dialogue with an artificial intelligence chatbot are nothing more than texts mechanically generated from the

texts it was trained with. In reality, the chatGPT chatbot does not think, but only provides linguistically similar answers to the content it was trained on. If the training content has errors, the answers returned by the chatGPT chat will also likely contain errors.

Three affordances of chatbots

Artificial intelligence algorithms have evolved in three broad moments. The first is the mechanical use of data, such as the abovementioned examples. They are numerical calculations that optimise our activities and, as I mentioned, can be used to optimise the transit route or the content of a playlist. This first moment of use has been called cognitive artificial intelligence.

A second use of generative artificial intelligence concerns the processing of human emotions. In this next stage of development, chatbots can identify emotions such as people's sadness, joy, or anger. This results in an apparent, more profound understanding of the commands we give to the chatbot. Phrases that are trivial to us as humans, such as saying good morning or thank you, or even the tone in which we write a sentence when we are angry, are more easily interpretable by artificial intelligence algorithms at this stage. This is affective artificial intelligence.

The sum of the two previous moments of use has led to the development of a recent third stage, which generative artificial intelligence chatbots use. This is artificial empathy. In this stage of development of computer programmes, the interaction is even more fluid because the chatbot learns from the text it was initially trained with, and from the interaction with the user itself. As a result, the response sentences returned by the chatbot are consistent with our cognitive and emotional state. Replies from chatbots can detect emotional states and reply accordingly.

These stages of generative artificial intelligence software development have led people to change the uses of chatbots. This change in uses has happened at a dizzying pace. It has migrated from simple searches for factual information or technical assistance to asking more sophisticated questions related to content creation and editing, not only of text but also of photos and videos, and even personal and professional help.

Actual use of chatbots

A recent study by Harvard University has monitored the uses people make of generative artificial intelligence

chatbots. In 2024, the top three uses of chatbots included idea generation, therapeutic consultation, and use of the chatbot as a companion, followed by specific searches for information. In the 2025 update, this report reports chatbot use as therapy and companionship, followed by two new uses. They relate to organizing one's personal life and finding meaning and purpose. The first use associated with therapy in companionship involves the guidance and support that the chatbot can give in the face of psychological problems or discomfort, such as grief or a traumatic event, while the use as companionship refers to establishing a social and emotional connection and can even reach romantic dimensions. The second use of the chatbot as an aid to organising life refers to analysing daily habits, following up on New Year's goals, and finding ways to optimise time. In this way, the chatbot becomes a personal and professional assistant. Finally, the third use of finding life purpose relates to using the chatbot to identify personal values and aspirations, as well as finding ways to reframe personal problems that may be blocking personal fulfilment, and also as an aid to stay focused on achieving the goals that give meaning to one's life.

At this point, it is worth mentioning that people have been concerned with the search for happiness and transcendence since the beginning of time. This has to do with different definitions of what we daily refer to as well-being. There are various types of well-being. Firstly, we can mention hedonic well-being, which, since the ancient

Greeks, was defined as the pursuit of pleasure and happiness for its own sake, as the most essential value in life. Whether in eating, resting, or social relations, hedonic well-being is simply the pursuit of pleasure. Another philosophical stream, which also comes from the ancient Greeks, was very critical of the pleasure focus of hedonism and, in response, came up with the definition of eudaimonic well-being, which focuses on the search for transcendence and self-realisation of people. That is, to go beyond what we usually are, to seek meaning in life in everything we say and do.

And this is where the relationship between people's well-being and interaction with generative artificial intelligence chatbots comes in. Initially, it may seem shocking to ask a computer programme about the meaning of our lives when we used to ask such questions to old sages, priests, or even psychologists, or questions that come up in discussions with our friends and family. Thus, the question arises: Is it possible to find well-being in its different dimensions using generative artificial intelligence chatbots?

The bright side of Gen AI for well-being

The initial answer seems to be yes. For the use of chatbots as therapy and companionship, one of the participants in the Harvard University report mentions the lack of psychologists available 24/7 to deal with psychological emergencies and adds that the confidentiality of data does not matter to him because sometimes life itself can be at risk. Another participant mentioned that since many people are lonely nowadays, chatbots have become a way to engage in conversation and develop social relationships. Companies are experimenting with artificial intelligence-based digital friend conversions to address the problem of loneliness. The company nemora.ai even offers generative artificial intelligence applications that allow users to interact with artificial intelligence girlfriends, providing realistic and personalised conversations.

As for using the chatbot as an assistant to organise one's life, the answer also seems to be yes. Some companies already offer their customers a chatbot that allows them to schedule appointments, such as with doctors, lawyers, and other specialists, without the need for people to spend a lot of time going through regular calendars to find the best time. For example, the startup planners.ai offers digital chatbots that help take notes, develop personal and work goals, and regularly track the completion of projects. In this way, it seems that a boss is no longer necessary to monitor people's progress in a workplace. Moreover, even for those with a gardening hobby, the startup galaxy.ai offers a chatbot to generate a schedule for planting flowers or vegetables based on the size of the garden, the weather, daylight hours, and soil type.

Finally, and in what seems to me the most sensitive topic of asking a chatbot about the meaning of life, it is also plausible to ask the chatbot questions about values, principles, and life aspirations. Participants in the study mentioned above indicate that the chatbot has helped identify how to translate those personal values into activities that enrich personal self-fulfilment, or what has helped people to increase their levels of introspection that lead them to remove some mental barriers.

The dark side of Gen AI in well-being

Now, while the above uses of chatbots are interesting and can lead to identifying ways to be better people and professionals. Recall that generative artificial intelligence algorithms learn from the texts they were initially trained on and from interactions with users. For example, suppose a person with severe depression interacts with a chatbot. In that case, the chatbot may mistakenly generate a conversation that includes responses that encourage self-harm, because other similar conversations have fed the algorithm. This poses significant risks to the mental health of people who are paradoxically seeking relief.

Another latent risk relates to the need for companies to keep users engaged. This may result in chatbots promoting the idea that links with artificial intelligence are better than links that can be established with people. It is therefore necessary to consider the interaction between the business model of generative AI startups and people's goals, in a way conducive to well-being rather than just increasing user engagement. How to avoid mistakes in replying to people's most inner concerns in an adaptive manner is still to be discovered, or even better, coded into the computer algorithm that rules chatbots' behaviours.

What's next?

The above benefits and risks suggest that we must carefully assess the influence of user interactions with generative artificial intelligence chatbots to understand their impact on people's well-being. Above all, we must know whether chatbots complement or replace human therapists or personal assistants, and to what degree personal interaction with these chatbots is healthy. Generative artificial intelligence will continue to evolve rapidly, but we must be equally quick to assess its influence on people's happiness and self-actualisation.

To learn more

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Task Hub: A Technology-Mediated Approach to Enhancing Family Collaboration and Responsibility

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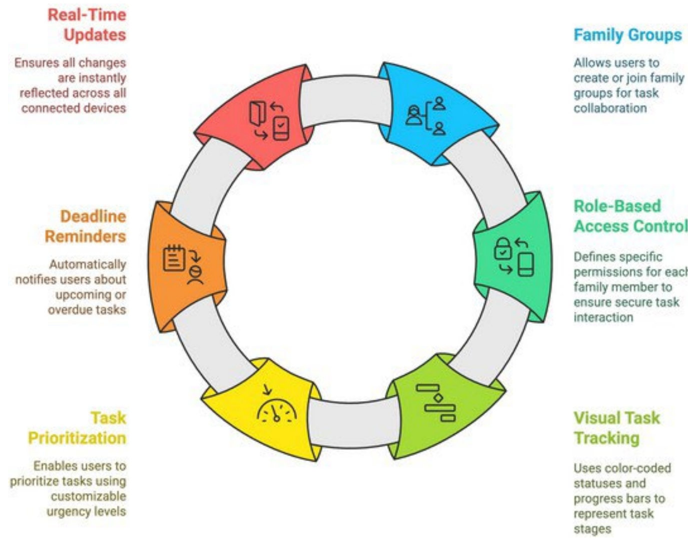
Task Hub is a web-based family task management platform designed to improve day-to- day household activity tracking through collaborative features. It extends beyond a simple to-do app by enabling family-wide coordination with role-based access control, visual task monitoring, and real-time updates. In this paper, we present the motivation and design of Task Hub, review related family task management solutions, and describe the system's architecture built with Next.js, NextAuth.js, MySQL, and RESTful APIs. Key features include family grouping for shared task lists, parent/child role distinctions, color-coded status indicators with progress bars, priority-level tagging, deadline reminders, and instant synchronization across devices. Primarily intended for academic evaluation, this project draws upon interdisciplinary principles from human-computer interaction, family dynamics, and potentially educational psychology. We evaluate how Task Hub addresses shortcomings of traditional personal task trackers – such as lack of multi-user support, limited accountability, and insufficient child-friendly interfaces – by facilitating meaningful collaboration and accountability within families.

Introduction

Managing household tasks is often stressful, especially when coordination is poor. Traditional methods like paper chore charts or basic to-do list apps are usually designed for individuals, not families. They lack real-time updates, accessibility, and shared accountability, leading to forgotten tasks, duplicated efforts, and a disproportionate mental load on one person—typically a parent. Digital collaboration tools can help reduce this burden by promoting shared visibility and responsibility. Studies show that families using shared task systems report lower stress and more quality time together. Transparent to-do lists ensure nothing slips through the cracks and encourage mutual support. While several family task apps now exist, many fall short in offering real- time collaboration or role-specific controls.

To address these gaps, we developed Task Hub—a web-based family task manager created as a collaborative academic project. Unlike generic productivity tools, Task Hub is tailored for family use, offering features like role-based access (e.g., parents with full control, children with limited views), real-time sync, task delegation, priorities, and reminders—all in one system. The following sections outline related work, our design methodology, system architecture, and evaluation. We highlight how Task Hub's features directly address limitations in traditional methods and existing apps, supporting more effective and inclusive family coordination.



Literature Review

Early task management tools were built for individual use, lacking the collaborative features needed for household coordination. Families often relied on whiteboards or paper lists, which didn't offer real-time updates or remote access. Later, digital tools like Todoist and Google Tasks allowed basic list sharing but remained limited in handling recurring household chores or supporting role-specific features. As a result, tasks often got buried under unrelated items, and users spent more time organizing than completing them.

Collaborative scheduling tools, such as Cozi and Cupla, go further by integrating shared calendars and task lists. Cupla reports that 70% of users felt less stress and improved quality time after switching to shared systems, reinforcing findings that shared responsibility reduces mental load.
Even general-purpose tools like Trello have been adapted for home use, thanks to their intuitive visual interfaces. From these apps and user feedback, several core requirements for effective family task systems emerge:

- Multi-user collaboration with transparency on task ownership.
- Role-based access control for age-appropriate responsibilities.
- Visual and intuitive task tracking to show progress and status clearly.
- Priority and scheduling features, including reminders and due dates.
- Real-time sync to keep all members updated.
- Automated notifications to prevent missed tasks.

Some apps also include extras like grocery lists or allowance tracking, but the main goal is shared coordination without overburdening a single person. Task Hub builds on these foundations, addressing the shortcomings of earlier apps by combining collaborative lists, role-based permissions, visual tracking, and real-time updates into one robust platform. Designed as a modern web solution, it aims to streamline household task management while promoting meaningful participation across all family members.

Methodology

The development of Task Hub followed a user- centered, iterative approach tailored for an academic setting. We began with informal interviews and observations of real families to understand pain points in managing household tasks. Common challenges— like lack of child-specific views, outdated task updates, and mental overload for parents aligned with our literature findings and helped define core requirements such as role-based access, real-time syncing, and intuitive task tracking.

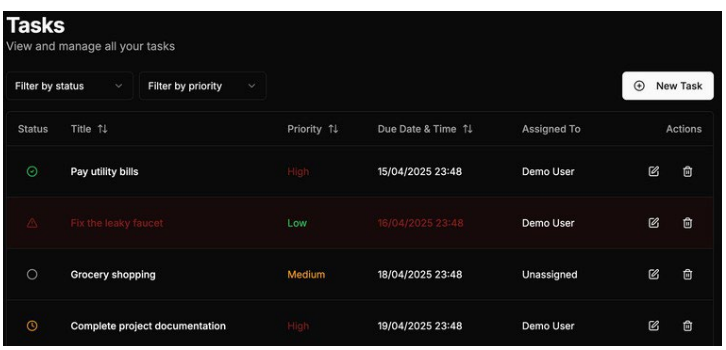
We designed the system around two user roles: Parent and Child. Use-case scenarios—such as assigning tasks, marking completion, or checking family progress—guided our interaction design. We adopted Role-Based Access Control (RBAC) to enforce appropriate permissions: parents can manage all tasks, while children have limited access to only their assignments. This model mirrors real-world family hierarchies and simplifies permission logic. Our technology stack was selected to meet the project's needs for collaboration, responsiveness, and security:

- Frontend: Built with Next.js (React) for dynamic UI and server-side rendering.
- Authentication Handled by NextAuth.js, enabling secure, role-based login.
- Database: MySQL, chosen for relational integrity and scalability.
- API Architecture: RESTful APIs (via Next.js routes) for clean backend/frontend separation.
- Styling: Tailwind CSS for rapid, responsive, and accessible UI design.

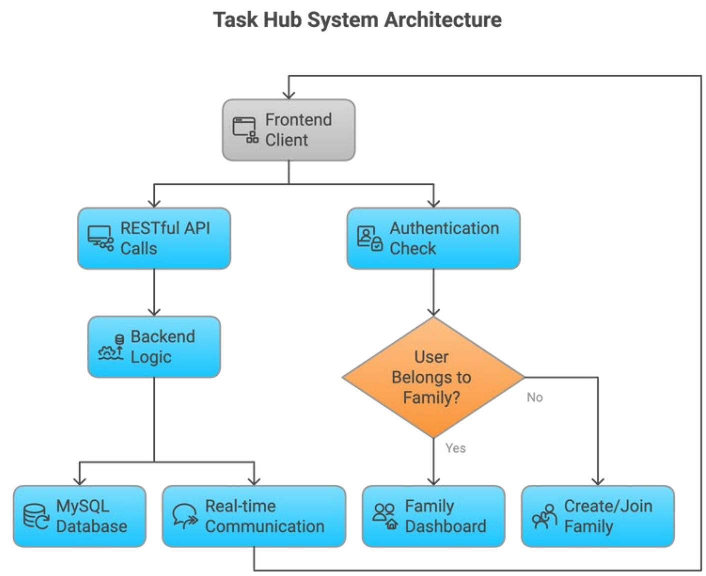
Development proceeded in modules, starting with user authentication and family grouping. We then implemented core features like task creation, assignment, status updates, and prioritization with visual indicators (e.g., color-coded labels).

System Design & Architecture (1)

Task Hub's system architecture follows a typical multi-tier web application model, with clear separation between the user



interface, server logic, and database. Figure 1 outlines the high-level architecture. The frontend client (running in the browser) is a Next.js application that serves the UI and interacts with backend services through RESTful API calls. The backend logic is handled by Next.js API routes (Node.js server functions) which process requests and perform database operations via an ORM or query builder for MySQL. The data persisted in a MySQL database that stores information about users, families, and tasks. We also integrated a real-time communication mechanism (using WebSockets) to broadcast task updates to all connected clients in a family, ensuring instant synchronization. Frontend/UI: The client side is built with Next.js and Tailwind CSS, providing a single-page application feel with interactive React components. Upon loading, the app checks authentication status via NextAuth. After login, the user is presented with a family dashboard if they belong to a family group, or an option to create/join a family.



Backend API: (4)

The backend is organized as a set of RESTful API endpoints under /api/ in the Next.js project. Notable endpoints include:

- POST /api/tasks – for creating a new task (with JSON payload containing title, description, assignee, priority, due date, etc.)
- GET /api/tasks – for retrieving the list of tasks for the authenticated user's family.
- PUT /api/tasks/[taskId] – for updating a task's details or status. Different sub-operations within this route have role checks: marking a task as completed can be done by the assignee or a parent, but reassigning or editing the task is limited to parents.
- GET /api/users – to fetch basic info about family members (names, roles) to display on the dashboard.
- These APIs are secured by NextAuth's session token – only logged-in users can access them, and each request carries the user's identity so that server-side handlers can enforce that a user only manipulates their own family's data

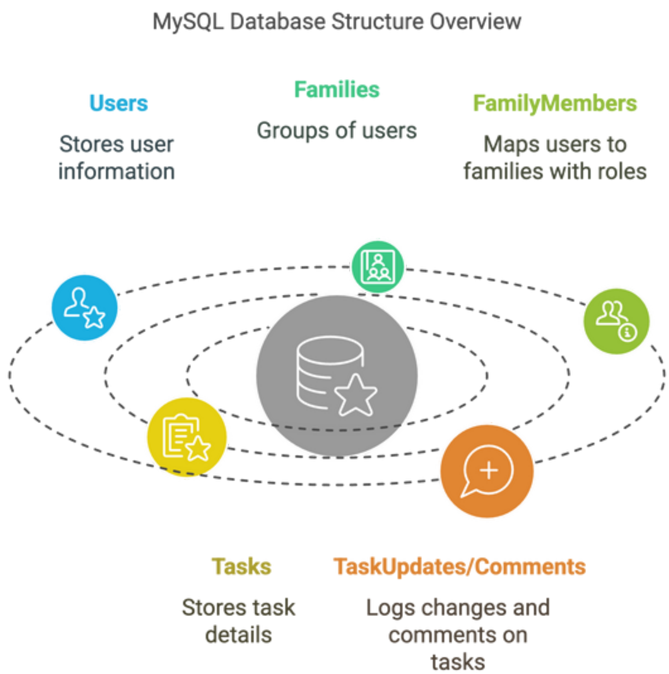
Authentication & Role Management:

Authentication in Task Hub is handled by NextAuth.js, configured for credential-based login (email and password for each user). User

accounts in the database have a role field (e.g., "parent" or "child") and a family group ID. NextAuth sessions store this information so that each API request knows the user's identity and role. We implemented role-based access control (RBAC) both on the client (to show/hide UI elements) and on the server (to protect endpoints). For instance, the API route for creating a new task will first verify that the requesting user is a parent (if, by design, only parents can create or assign tasks). This follows the RBAC principle of associating permissions with roles, simplifying enforcement of rules.

Database Design: (2)

The MySQL database has tables such as Users, Families, Family Members (to map users to a family with a role), and Tasks. The



Tasks table stores fields like task_id, family_id (to associate the task with a specific family), title, description, assignee_user_id, status (an enum of, say, {NotStarted, InProgress, Completed, Overdue}), priority (e.g., Low, Medium, High), *due_date, created_at, updated_a*t. Additional tables include Task Updates or Comments if we allow commenting or logging changes on tasks. This schema ensures that tasks and users are always tied to a family context, which is crucial for multi- user collaboration in distinct groups.

Implementation:

The implementation of Task Hub focused on secure family collaboration, task lifecycle management, and real-time synchronization using database-driven methods.

Family Grouping & Membership:

Users are assigned a family_id and role in the Users table. When a parent creates a family, a new record is added to the Families table, and the parent's role is set as 'parent'. Invite-based onboarding is implemented via unique tokens stored in an Invites table, verified during registration. This ensures controlled group formation.

RBAC (Role-Based Access Control): (3)

Access to critical operations (e.g., assigning tasks, editing others' tasks) is restricted based on roles (parent, child, admin). Backend APIs enforce RBAC through middleware that inspects the session context before route execution. Frontend components use role-aware conditional rendering, for instance, only parents see task creation or role assignment options. Children are directed to a minimal dashboard showing only their assigned tasks

Visual Progress Tracking:

Task cards are color-coded using Tailwind CSS based on status: grey (not started), yellow (in progress), green (complete), red (overdue). Tasks with subtasks display dynamic progress bars based on the ratio of completed sub-tasks. Additional icons (e.g., bell for due soon, star for high priority) enhance visual scanning.

Reminders via MySQL Events:

Reminders are triggered using the MySQL EVENT scheduler, which runs every hour. It checks for tasks nearing their deadline or already overdue and writes to a Notifications table. A polling system on the client checks these reminders and prompts users with toast alerts or emails. This avoids the need for external cron jobs or message queues.

Real-Time Sync via MySQL Triggers:

Instead of WebSockets, we used AFTER INSERT/UPDATE triggers on the Tasks and TaskAssignments tables to log changes into a TaskChanges table. Clients poll this lightweight change log every few seconds, scoped to their family_id, to fetch the latest deltas. The frontend then patches the local state, accordingly, providing near-real-time sync without persistent connections.

Performance & UX Optimizations:

Database queries are optimized with indexes on *family_id*, *assignee_id*, and due_date. On the frontend, react state updates are diff-based to reduce re-renders, and lightweight caching minimizes duplicate fetches. The UI is responsive, and tailored parents get full control panels, while children see simplified views. We also prototyped a badge reward system to gamify task completion for younger users.

Evaluation

To assess the effectiveness and usability of Task Hub, we conducted a week-long pilot study with three volunteer families. Each family received demo accounts and a brief tutorial. We collected qualitative feedback via interviews and surveys, alongside usage logs to observe real-world behavior. This preliminary evaluation was complemented by a proposed framework for future large-scale validation.

User Feedback

RBAC (Role-Based Access Control) was positively received—parents felt confident letting children use the app, knowing they couldn't delete or reassign tasks. Older kids (13–15) expressed interest in suggesting or claiming tasks, a feature not currently supported but worth exploring.

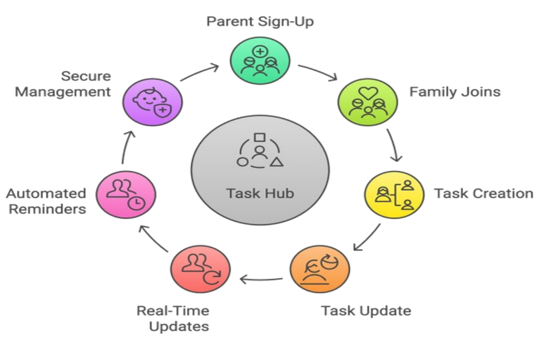
Future Evaluation Strategy

To further validate Task Hub's impact, a mixed- method evaluation is proposed:

- Qualitative: Interviews and surveys focusing on usability, role clarity, visual tracking, and family coordination.
- Quantitative: Metrics such as task completion rate, frequency of usage, and feature engagement.
- Usability Testing: Sessions involving guided tasks to assess the intuitiveness for both adults and children.
- Ethical Considerations: Strict adherence to data privacy, child safety, and informed consent practices.

Discussion

Task Hub addresses key limitations of traditional task trackers by introducing a collaborative, role-based system tailored for families. Compared to apps like OurHome or FamilyWall, Task Hub offers a more seamless and secure experience through strict RBAC enforcement and flexible use cases—from chores to trip planning or project coordination.



Conclusion

In conclusion, the "Task Hub" project presents a promising technology-driven solution to the challenges faced by modern families in managing daily tasks and fostering responsibility, particularly in children. By offering a suite of advanced features such as family collaboration, role-based access, and visual task tracking, "Task Hub" has the potential to enhance household efficiency, improve communication, and cultivate a greater sense of shared responsibility within the family unit.

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Afforestation for Sustainable Growth in India

Indian afforestation efforts include ambitious national commitments to increase forest cover, restore degraded lands, and create carbon sinks to meet climate goals, supported by schemes like the National Afforestation Programme (NAP) and the Green India Mission (GIM). India aims to expand its forest and tree cover to 33% and restore 26 million hectares by 2030, creating an additional carbon sink of 2.5-3 billion tones of CO_2 equivalent. India has pledged to create an additional 2.5 to 3 billion tones of CO_2 equivalent carbon sink by 2030 through forest and tree cover expansion. The nation aims to increase its total forest and tree cover from its current levels to 33% of its geographical area.

Source: AI Compilation

Science, Technology and Initiatives in India Consciousness and

Digital Global Climate Sustainability

Research and Development Digest (RDD) as an initiative of India-Mexico Research Consortium (IMRC), to bring together the thematic research on science, technology, humanities, and business has began in 2023. This is a quarterly publication of IMRC under the aegis of Embassy of India in Mexico. RDD has completed Volume 1 and is moving ahead with Volume 2. Thanks for your valuable support.

IMRC: Research and Development Digest V2 N2
Call for Papers on Education, Entrepreneurship, and Economy
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- Education policies and programs
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- Skill development and empowerment
- SDGs and socio-economic compliance
- Women, entrepreneurship and economy
- Government initiatives, CSR, and PPP
- Higher educational institutions.

Length of submission: **Between 1000 and 2500 Words** | Language: English (USA)

Formatting: Article Body [Times New Roman (TNR) 11 Font], Title (TNR 11, Bold, Centre), Author name and affiliation (TNR10, Centre), Section heading (TNR 11, Bold, Centre), Sub-section headings (TNR 11, Italics, Centre), Bullets and numbering (TNR11, left indent), References (APA 7th Edition Style), Footnotes as required, page numbers (TNR 10, Corner, Right)

Please submit your contribution by **October 31, 2025** to the Editor, IMRC Research and Development Digest at imrcnetwork@gmail.com