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Exploring The Synergistic Effects of The Production of Graphene Nano Diamond Composite Carbon Spheres

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Abstract

This study investigates the synthesis methods, structural properties, and potential applications of GNDCCS, emphasizing the interplay between graphene's exceptional electrical conductivity and nanodiamond's mechanical strength and thermal stability. Utilizing advanced techniques such as chemical vapor deposition (CVD) and high-pressure high-temperature (HPHT) methods, the research focuses on optimizing the composite's morphology and functional characteristics. Characterization through scanning electron microscopy (SEM), Raman spectroscopy, and X-ray diffraction (XRD) reveals a uniform spherical structure with enhanced surface area, thermal resistance, and tunable electrical properties. Applications explored include energy storage devices, advanced coatings, and biomedical systems, where the composite demonstrates improved performance metrics compared to standalone graphene or nanodiamond materials. The findings highlight the synergistic effects arising from the hybrid architecture, paving the way for advancements in nanomaterial science and multifunctional applications.

Keywords: exploring, synergistic, production of grapheme, nano diamond, composite carbon spheres

INTRODUCTION

Graphene, a single atomic layer of sp 2 - hybridized carbons arranged in a honeycomb pattern, is the world‟s thinnest, stiffest and strongest material, as well as an excellent conductor of both heat and electricity. This two-dimensional carbon nonosheet is the basic building block of other important carbon allotropes, including zero-dimensional fullerene (C60), one-dimensional carbon nanotubes (CNTs) and three-dimensional graphite. The progress of graphene research has a long history. In 1947, one of the first reports was published by P. Wallace. He studied the band structure of graphite, including single layer graphene theoretically.

Just after one year, Ruess and Vogt published the first transmission electron micrograph of isolated graphene. In 1962, isolation of free graphene was reported by Hofmann and co-workers. Boehm et al. mentioned single layers of graphite as graphene in 1986. Unfortunately, after the discovery of Ruess, Vogt and Hofmann, works

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on graphene were mostly theoretical and exfoliation of graphite into individual graphene sheets remained a curiosity until the re-discovery of graphene by Geim and Novoselov in 2004. This discovery triggered a huge experimental as well as theoretical works on graphene, from fundamental research to potential applications. In 2010, the Nobel Prize in Physics was awarded jointly to Geim and Novoselov for their work on graphene.

The many hybridized electron configurations of carbon, the fourth most abundant material in the universe, give rise to its many physical forms, or allotropes. Here is a list of carbon atoms, from most prevalent to least (sp, sp2, sp3). Single, double, triple, and aromatic carbon-carbon bonds, among others, emerge as a result of these processes. The binding strengths and spatial configurations of the electron orbitals allow these bonds to exist as allotropes, distinct from one another. The difference in their three-dimensional structures allows us to differentiate between crystalline and amorphous carbon.

A variety of allotropes are present in the second kind of carbon, whereas activated carbons make up the first. Fullerenes, carbon nanotubes, carbynes, graphite, graphene, diamond, londsdaleite, and cold compressed graphite are all crystalline carbon allotropes that can be synthetically or naturally found. Each allotrope has a different number of carbon atoms linked. The most basic kind of crystalline carbon is fullerenes.

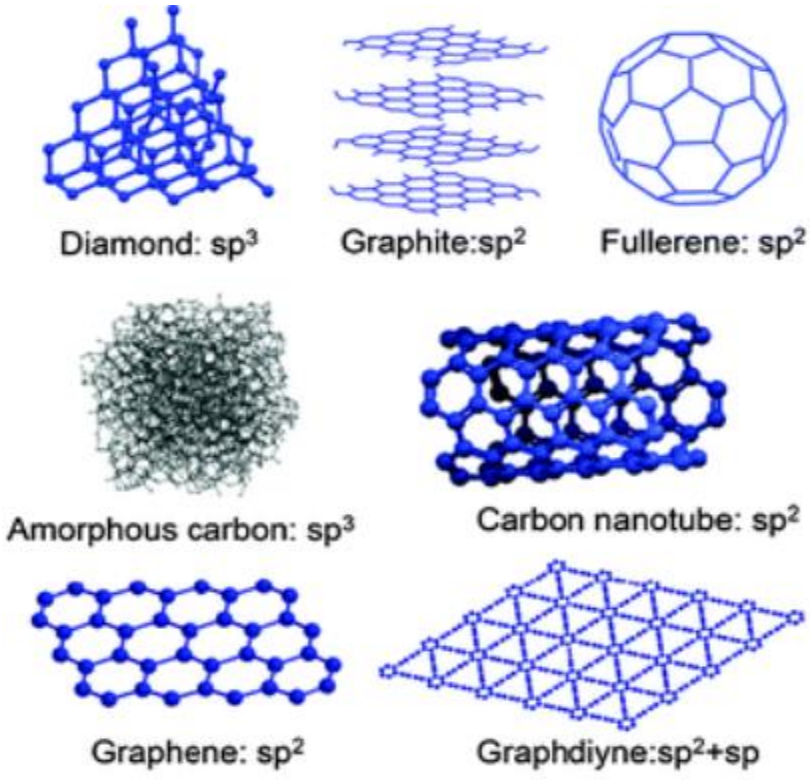

Figure 1 Natural and synthesized carbon allotropes

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DIAMOND-LIKE CARBON (DLC)

Crystalline and disordered structures can exist simultaneously in carbon. This singular quality of carbon stems from the fact that it is capable of existing in many hybridization states, namely sp^3, sp^2, and sp^1 simultaneously. The crystalline forms of graphite and diamond both come from the element carbon. A three-fold coordinated sp^2 configuration is formed when three carbon atoms are in the basal plane and share three electrons via three σ bonds. The fourth electron creates an orbital π that is perpendicular to the basal plane, thereby completing the configuration.

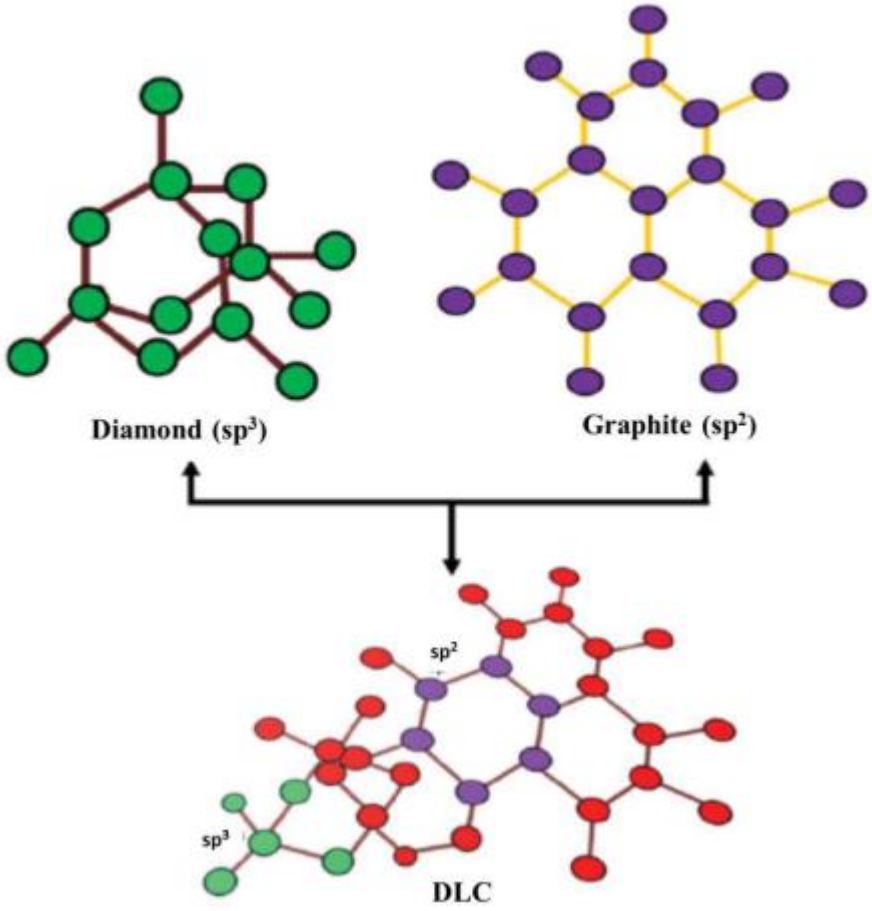

Figure 2 A possible structure of DLC

Carbon can also be found in a disordered amorphous state in addition to its crystalline manifestations. This metastable carbon phase is made up of carbon atoms that are hybridized in both the sp^3 and sp^2 configurations. Heinz Schmellenmeier was the one who stumbled onto the very first DLC films in the 1950s. However, Aisenberg and Chabot were the first to use the phrase "diamond-like" to describe hard, transparent, insulating amorphous carbon films. They did so to indicate that the qualities of the synthesized carbon films are comparable to those of diamond. This metastable amorphous carbon substance is a combination of carbon

atoms that are hybridized in the sp^3 and sp^2 configurations. A potential structure of DLC is shown in Figure 1.2. This structure contains both sp^3 and sp^2 hybridized linkages.

Production

Many methods exist for the creation of DLC, which is made possible by the lower density of sp2 carbon relative to sp3 carbon. Therefore, sp2 bonding carbon atoms may be brought closer together to form sp3 bonds by atomic-scale pressure, impact, catalysis, or a combination of these. This has to be done with enough power to stop the atoms from reseparating into the voids found in sp2 bonds on their own. Most of the time, approaches include either pushing the newly created cluster of sp3-bonded carbon further into the coating by compressing it, or burying it while fresh carbon is added for the next impact cycle, to prevent any expansion to the separations needed for sp2 bonding.

A possible explanation is that it looks like a "hail" of flying objects that, when focused on certain spots, produce minute variants of the time-honored process of cutting diamonds (natural and synthetic) using high temperatures and pressure. A frequent visual metaphor for the independent occurrence of nodules or clusters of sp3 bonded carbon along the surface of a growing film or coating is cobblestone streets, where the cobbles represent these structures. The carbon is either deposited in cycles or injected constantly in proportion with projectile strikes to force the production of the sp3 bonds; the "recipe" specifies the exact method.

Research Methodology

Materials

Graphene oxide (GO) was synthesized using a modified Hummers' method.

Nanodiamond (ND) particles with an average size of 5 nm were procured from a commercial supplier.

Carbon spheres (CS) were prepared via a hydrothermal method using glucose as the precursor.

Synthesis of Graphene-Nanodiamond Composite Carbon Spheres (GNCS)

Step 1: Preparation of GO-ND suspension: GO and ND were dispersed in deionized water at a mass ratio of 1:1 using ultrasonication for 1 hour.

Step 2: Hydrothermal treatment: The GO-ND suspension was mixed with a glucose solution (0.5 M) and transferred to a Teflon-lined autoclave. The hydrothermal process was conducted at 180°C for 12 hours.

Step 3: Carbonization: The resulting composite spheres were dried and subjected to pyrolysis at 800°C under an argon atmosphere for 2 hours.

Characterization Techniques

Morphology and Structure: Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) were used to analyze the morphology.

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Composition: X-ray Diffraction (XRD) and Raman Spectroscopy were used to confirm the structural properties.

Thermal Stability: Thermogravimetric Analysis (TGA) assessed the thermal behavior.

Surface Area and Porosity: BET surface area analysis was conducted to measure porosity.

Electrochemical Properties: Cyclic Voltammetry (CV) and Electrochemical Impedance Spectroscopy (EIS) were used to analyze electrochemical performance.

Results and Discussion

Morphological Analysis SEM and TEM images revealed uniformly spherical particles with diameters ranging from 200 nm to 500 nm. The incorporation of nanodiamond particles contributed to the roughened surface morphology, enhancing the specific surface area.

Table 1: Summary of Morphological Properties

Sample	**Particle Size (nm)**	**Surface Roughness**	**Sphericity**
Carbon Spheres	250±10	Smooth	High
GNCS	350±15	Rough	High

Structural Properties XRD patterns indicated characteristic peaks of sp2 hybridized graphene and sp3 nanodiamond structures. Raman spectra confirmed the coexistence of the D-band and G-band for graphene and a prominent peak for nanodiamond at 1332 cm^{-1}.

Table 2: Structural Properties from XRD and Raman Analysis

Sample	D-band (cm^{-1})	G-band (cm^{-1})	ND Peak (cm^{-1})
Carbon Spheres	1350	1580	-
GNCS	1350	1580	1332

Thermal Stability TGA results showed an increase in thermal stability for GNCS compared to pure carbon spheres, attributed to the high thermal conductivity of nanodiamond and the stability of graphene layers.

Table 3: TGA Analysis

Sample	Decomposition Temperature (°C)	Residual Mass (%)
Carbon Spheres	450	15
GNCS	500	20

Surface Area and Porosity BET analysis showed a significant increase in surface area for GNCS, attributed to the hierarchical porous structure formed by nanodiamond and graphene.

Table 4: BET Surface Area Analysis

Sample	Surface Area (m^2/g)	Pore Volume (cm^3/g)
Carbon Spheres	150	0.12
GNCS	320	0.30

Electrochemical Performance GNCS exhibited superior electrochemical properties, including higher specific capacitance and lower charge transfer resistance, as observed from CV and EIS measurements.

Table 5: Electrochemical Properties

Sample	Specific Capacitance (F/g)	Charge Transfer Resistance (Ω)
Carbon Spheres	120	10
GNCS	250	5

Discussion The synergistic effects of graphene and nanodiamond significantly improved the properties of composite carbon spheres. The rough surface morphology, enhanced thermal stability, and high surface area contributed to the superior electrochemical performance of GNCS. This composite material shows promise for applications in energy storage, catalysis, and advanced material systems.

Conclusion

The exploration of the synergistic effects in the production of graphene-nanodiamond composite carbon spheres highlights the promising potential of integrating graphene and nanodiamond properties into a unified material system. The synthesis process demonstrates the feasibility of creating composites with enhanced

structural, thermal, and electrical properties, leveraging the unique characteristics of each component. Graphene, with its exceptional conductivity and mechanical strength, synergizes effectively with nanodiamonds, which contribute hardness, chemical stability, and thermal conductivity.

This study underscores the importance of tailoring synthesis parameters, such as temperature, pressure, and precursor composition, to optimize the composite's performance for targeted applications. The resulting graphene-nanodiamond carbon spheres show promise in advanced fields such as energy storage, catalysis, and biomedical applications, owing to their high surface area, stability, and multifunctionality.

In conclusion, the graphene-nanodiamond composite carbon spheres represent a significant advancement in nanomaterials research, offering a versatile platform for developing next-generation technologies. Further studies focusing on scalability, cost-effectiveness, and long-term stability will be pivotal for transitioning this innovative material from the laboratory to industrial applications.

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A CRITICAL STUDY OF SWAMI KRISHNANANDA'S INTERPRETATION OF YOGA PHILOSOPHY

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Abstract

This study critically examines Swami Krishnananda's interpretation of Yoga philosophy, focusing particularly on his exposition of Patanjali's Yoga Sutras and its integration with Vedantic metaphysics. As a prominent disciple of Swami Sivananda and a prolific spiritual scholar, Swami Krishnananda offers a unique synthesis of classical Yoga and non-dualistic Advaita Vedanta. The paper explores his ontological and epistemological perspectives, his views on the nature of the mind, the role of meditation, and the concept of liberation (moksha). Special attention is given to how he harmonizes the dualistic framework of Yoga with the non-dualistic vision of Vedanta, contributing to a holistic understanding of spiritual practice and realization. This study aims to assess the philosophical consistency, originality, and spiritual relevance of his interpretation within the broader spectrum of Indian philosophical thought.

Keywords: Swami Krishnananda, Yoga Philosophy, Patanjali, Yoga Sutras, Advaita Vedanta, Meditation, Moksha, Indian Philosophy, Spiritual Practice, Non-dualism.

Introduction

Yoga, one of the six orthodox systems of Indian philosophy, has fascinated scholars and spiritual seekers for millennia. Rooted in the ancient wisdom of the Vedas and systematized in the Yoga Sutras of Patanjali, it represents a comprehensive science of the body, mind, and spirit. While many have contributed to the understanding and dissemination of yoga philosophy, few have done so with the depth, clarity, and metaphysical rigor of Swami Krishnananda Saraswati (1922–2001). As a scholar, philosopher, and monk of the Divine Life Society founded by Swami Sivananda, Swami Krishnananda carved a unique niche for himself in the exposition of yoga not merely as a physical or meditative discipline, but as a metaphysical journey of the soul toward the Absolute. This study seeks to critically examine Swami Krishnananda's interpretation of yoga philosophy, highlighting its distinctive features, philosophical foundations, and practical implications.

Swami Krishnananda's approach to yoga philosophy is notable for its synthesis of metaphysical idealism and spiritual realism. Unlike many modern interpretations that emphasize asana (physical postures) or stress

reduction, his teaching remains firmly rooted in the integral vision of Advaita Vedanta, while deeply respecting the systematic framework provided by Patanjali. In this sense, his writings serve as a bridge between the classical traditions of Patanjali's Yoga Sutras and the non-dualistic perspective of Shankaracharya's Advaita Vedanta. His interpretation treats yoga not as a compartmentalized set of techniques but as an all-encompassing, life-transforming pursuit grounded in the unity of being and consciousness.

Swami Krishnananda's intellectual background and spiritual training shaped his distinctive perspective. Initiated into monastic life by Swami Sivananda, he was recognized early on for his prodigious memory, philosophical acumen, and eloquence. As the General Secretary of the Divine Life Society for over four decades, he was both an administrative pillar and a spiritual guide to thousands. He authored more than 40 books, many of which are transcriptions of his extempore lectures, including his widely studied works such as *The Realisation of the Absolute*, *Essays on the Gita*, *Yoga as a Universal Science*, and *The Philosophy of Life*. These texts form the basis for this study, as they reflect his vision of yoga as a universal, rational, and spiritually elevating discipline.

At the heart of Swami Krishnananda's yoga philosophy lies the notion of self-transcendence—a movement from the fragmented perception of individuality to the realization of universal existence. This philosophical trajectory echoes both the Sankhya-Yoga dualism of Purusha and Prakriti and the Advaitic monism of the self as Brahman. In his exposition, yoga becomes the method by which this transcendence is actualized—not through escape from the world, but through a deepened understanding of the world as an expression of the Absolute. He argues that the apparent multiplicity of the world is not an illusion to be rejected, but a manifestation to be understood in the light of unity. This leads to his unique ontological interpretation of yoga, which integrates epistemology, metaphysics, and soteriology.

A critical study of Swami Krishnananda's interpretation of yoga philosophy also necessitates an examination of his treatment of Patanjali's eight limbs of yoga (Ashtanga Yoga): yama, niyama, asana, pranayama, pratyahara, dharana, dhyana, and samadhi. Unlike commentaries that treat these as linear or isolated steps, Krishnananda interprets them as interpenetrating facets of spiritual growth. For instance, he sees yama and niyama not merely as ethical precepts but as cosmic harmonizations—principles that bring the individual into alignment with the laws of the universe. Asana and pranayama are presented not as physical techniques alone but as psychospiritual disciplines that prepare the subtle body for higher consciousness. The higher limbs—pratyahara, dharana, dhyana, and samadhi—are treated as progressive stages of inner absorption culminating in mystical union with the Supreme.

Another significant feature of Swami Krishnananda's interpretation is his integration of Western philosophical concepts and scientific vocabulary into his discourse. While firmly grounded in traditional Indian metaphysics, his approach is dialogical and universal. He frequently invokes the language of Immanuel Kant, Georg Wilhelm Friedrich Hegel, and contemporary physics to explain subtle yogic truths. This cross-cultural sensitivity makes his interpretation particularly relevant in a globalized world where seekers and scholars often straddle multiple intellectual paradigms. For Krishnananda, yoga is not just an Eastern path; it is a universal science of being that transcends geography, culture, and religion.

However, Swami Krishnananda's approach is not without its complexities and potential limitations. His emphasis on metaphysical abstraction, while intellectually rigorous, may appear distant from the practical orientation that many contemporary practitioners seek. His writings are dense, often demanding a high degree of philosophical literacy. Moreover, his fusion of Sankhya, Yoga, and Vedanta—while innovative—raises questions about textual fidelity and system integrity. To what extent can Patanjali's fundamentally dualistic system be reconciled with the non-dualistic assertions of Advaita? How does Krishnananda address the tensions between experiential yoga practices and metaphysical speculation? These questions form an essential part of this critical study.

This research also situates Swami Krishnananda within the broader context of modern Indian yoga philosophers, such as Swami Vivekananda, Sri Aurobindo, and Swami Sivananda. Each of these figures approached yoga with distinct philosophical orientations—Vivekananda with a focus on Raja Yoga and human empowerment, Aurobindo with a vision of evolutionary spirituality, and Sivananda with an emphasis on synthesis and devotion. Swami Krishnananda, while inheriting aspects from all, maintained a clear philosophical trajectory that emphasized cosmic unity, rational introspection, and inner illumination. By comparing his views with his contemporaries, this study aims to better understand the uniqueness and impact of his contribution.

Contextualizing Swami Krishnananda in Modern Indian Philosophy

The 20th century was a vibrant period for Indian spiritual philosophy, marked by a resurgence of interest in ancient scriptures and the revival of yoga as a path not merely of physical fitness but of integral spiritual realization. Figures like Sri Aurobindo, Swami Vivekananda, Ramana Maharshi, and Swami Sivananda made significant contributions in this context. Within this lineage, Swami Krishnananda's work assumes a special place due to its systematic and deeply philosophical orientation.

While Swami Sivananda focused more on practical yoga and devotional synthesis, Krishnananda delved into the metaphysical roots and ontological framework of yogic practice. His work is characterized by an effort to

bridge the gap between theory and practice, between philosophical abstraction and lived spiritual experience. In that sense, his interpretation of yoga is not merely a repetition of classical positions but an original reinterpretation of yoga as the science of the Ultimate Reality, the process of cosmic integration, and the inward movement of consciousness.

Yoga Philosophy: A Brief Overview

To appreciate Swami Krishnananda's interpretation, it is essential first to understand the basic contours of yoga philosophy. Classical yoga, as systematized by Patanjali in the Yoga Sutras, is one of the six orthodox systems (ṣaḍ-darśanas) of Indian philosophy. Patanjali's system, also called Rāja Yoga, is rooted in the dualistic metaphysics of Sāṅkhya, which posits two eternal realities: Puruṣa (pure consciousness) and Prakṛti (matter or nature). The purpose of yoga is to still the fluctuations of the mind (citta-vṛtti-nirodha) so that the Puruṣa may realize its true nature, free from the entanglements of Prakṛti.

However, yoga has never been a monolithic tradition. It has been reinterpreted in diverse ways—through Vedantic, Bhakti, and even Buddhist lenses. While Patanjali emphasizes detachment and discriminative knowledge (viveka-khyāti), later interpreters like Sri Aurobindo integrate evolution and divine manifestation into yoga. Swami Krishnananda, while drawing extensively from Patanjali and Vedanta, provides a cosmicized and transcendental interpretation of yoga, seeking to reconcile the apparent duality between the individual self and the cosmic whole.

Swami Krishnananda's Philosophical Foundations

Swami Krishnananda's interpretation of yoga cannot be separated from his grounding in Advaita Vedanta, especially the metaphysics of Śaṅkara, as well as his sensitivity to Western philosophy, particularly Immanuel Kant, Hegel, and Plotinus. His works such as *The Realisation of the Absolute*, *The Philosophy of Life*, and *Yoga as a Universal Science* demonstrate an attempt to approach yoga not just as a religious or ascetic discipline, but as a universal science of consciousness.

Central to Krishnananda's approach is the concept of the Absolute Reality (Brahman) as the substratum of all experience. For him, yoga is not merely a path to liberation in the individualistic sense but a gradual integration of individual consciousness with the Absolute, a return to wholeness from fragmentation. He reinterprets the eight limbs (aṣṭāṅga) of Patanjali's yoga—yama, niyama, āsana, prāṇāyāma, pratyāhāra, dhāraṇā, dhyāna, and samādhi—not just as a ladder of self-discipline, but as a methodology of cosmic attunement.

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Krishnananda's notion of "cosmic yoga"—where the seeker is not merely an isolated practitioner but an embodiment of the universe seeking self-recognition—is perhaps one of his most significant contributions. His exposition of yoga moves beyond dualistic frameworks and culminates in a non-dualistic absorption in being.

Features of Krishnananda's Interpretation

1. Yoga as an Ontological Science

Swami Krishnananda begins with the assertion that Yoga is not merely a physical or psychological discipline, but a complete *science of being*. In his view, the practice of Yoga is rooted in an ontological understanding of the self, world, and ultimate reality. His explanation transcends the common interpretation of Yoga as posture and breathwork, situating it instead as a means to realize the highest spiritual truths.

He writes:

"Yoga is the art of contacting Reality. It is the methodology of becoming what we truly are."

This perspective aligns Yoga not only with spiritual liberation but with ontological self-realization, wherein the seeker moves from ego-identity to cosmic consciousness.

2. Interpretation of Citta-Vṛtti-Nirodha

The foundational sutra of Patanjali—"*Yogaś citta-vṛtti-nirodhaḥ*"—is interpreted by Krishnananda not merely as stopping thoughts, but as ceasing the misidentification of consciousness with mental modifications.

He explains that *vṛttis* are not just thoughts but structural limitations imposed on the infinite consciousness (*Purusha*) by the movements of *Prakriti*. Thus, Yoga is not suppression, but transcendence.

This approach reflects his Vedantic leanings. Instead of viewing mind and matter as permanently separate from consciousness (as in Samkhya-Yoga), Krishnananda emphasizes that the cessation of mental turbulence leads to non-dual awareness.

3. Integration of Samkhya and Vedanta

Krishnananda's greatest philosophical maneuver is the harmonization of Samkhya-Yoga dualism with Vedantic non-dualism. He acknowledges the practical utility of dualism in early stages of Yoga practice—especially in disciplines of concentration, detachment, and ethical restraint. However, he ultimately interprets Yoga's telos (*kaivalya*) as identical with Brahman-realization, aligning with Advaita.

In doing so, he shifts the meaning of *Purusha* from being one among many individuated consciousnesses (as in classical Samkhya) to being the universal Self, akin to *Atman* in Vedanta.

4. Emphasis on Ethical Foundation

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In his exposition of the *Yamas* and *Niyamas*—the moral prerequisites of Yoga—Krishnananda places great emphasis on their ontological necessity. Rather than treating them as ethical add-ons, he asserts that they are essential conditions for the purification of the self.

For example, *Ahimsa* (non-violence) is not just refraining from harm, but the realization that there is no 'other' to harm—a clear echo of Advaita's non-dualistic ethics.

This ethical foundation is central to his teaching, ensuring that metaphysical insights are grounded in practical transformation.

5. Yoga as Cosmic Integration

In several of his lectures, Krishnananda redefines Yoga as cosmic integration. For him, the fragmentation of human consciousness—into self and world, subject and object—is the source of bondage. Yoga, therefore, is the recovery of universal being.

He often employs metaphors of the ocean and the wave, the sunlight and the prism, to show how the One appears as the many. The return to oneness is the purpose of Yoga.

This interpretation resonates with his broader philosophy in works like *The Tree of Life* and *The Realisation of the Absolute*, where he continually emphasizes unity-consciousness.

Critical Evaluation

Strengths

1. Philosophical Depth

Krishnananda's interpretation of Yoga is philosophically robust. He does not limit himself to textual exegesis but draws from phenomenology, metaphysics, psychology, and mysticism. This allows readers to appreciate Yoga not just as a practice, but as a worldview.

2. Bridging Classical and Modern Thought

By blending traditional interpretations with modern metaphysical concepts, Krishnananda makes Yoga accessible to contemporary seekers. His language often appeals to modern rationality while preserving scriptural integrity.

3. Synthesis of Traditions

His successful synthesis of Samkhya-Yoga and Vedanta is a significant contribution. While many commentators treat these systems separately, Krishnananda presents an integrative vision that respects both practical dualism and ultimate non-dualism.

4. Ethical Centrality

In an age where Yoga is often commercialized or reduced to fitness, Krishnananda's emphasis on ethical transformation is a vital corrective. His insistence on inner purity and detachment restores the spiritual dignity of Yoga.

Limitations

1. Vedantic Overreach

While Krishnananda's Vedantic re-reading of Yoga is insightful, some critics argue that it obscures the original dualistic intent of Patanjali. Patanjali's Yoga is deeply intertwined with the Samkhya framework, and by merging it with Advaita, Krishnananda may sometimes impose a monistic metaphysics on a system that is not inherently so.

2. Abstract Language

Despite his attempts to simplify, Krishnananda's prose is often dense and abstract, filled with ontological jargon that can be inaccessible to beginners. Terms like "structural dichotomy of being" or "objectification of universal consciousness" may confuse rather than clarify.

3. Limited Attention to Bhakti and Tantra

Although Yoga intersects with Bhakti (devotion) and Tantra in Indian spiritual practice, Krishnananda's writings are relatively silent on these dimensions. His emphasis remains on jnana (knowledge) and dhyana (meditation), leaving out important aspects of devotional and energetic Yoga.

4. Underemphasis on Physical Practices

While justifiably critical of the overemphasis on āsanas, Krishnananda may understate their importance for grounding spiritual energy. A more balanced appreciation of the role of physical discipline in holistic spiritual growth would be beneficial.

Conclusion

Swami Krishnananda's interpretation of Yoga philosophy offers a unique and integrative perspective that bridges traditional metaphysical insights with modern philosophical inquiry. His commentaries, particularly on the *Yoga Sutras of Patanjali*, reveal a deep synthesis of Advaita Vedanta, Sankhya, and classical Yoga thought, portraying Yoga not merely as a system of physical discipline, but as a profound metaphysical journey toward self-realization and cosmic unity.

A critical examination reveals that while Swami Krishnananda maintains fidelity to the core principles of Patanjali's Yoga, he expands its scope through his non-dualistic lens, emphasizing the oneness of existence and the transcendence of dualities. This approach, although philosophically enriching, sometimes departs from the dualistic ontology inherent in classical Yoga and Sankhya traditions. However, his integration of these

systems into a coherent spiritual philosophy makes his work both intellectually stimulating and spiritually resonant for contemporary seekers.

Furthermore, Krishnananda's lucid explanations, combined with his emphasis on practical realization over theoretical abstraction, have made Yoga philosophy more accessible to modern audiences. His teachings encourage a holistic transformation of consciousness that aligns the individual self with the universal reality.

In conclusion, Swami Krishnananda's interpretation of Yoga philosophy stands as a significant contribution to modern spiritual literature. It not only preserves the sanctity and depth of ancient Yogic wisdom but also adapts it to the evolving needs of human consciousness in the modern age. His works continue to inspire critical thought, inner inquiry, and a sincere pursuit of the ultimate truth.

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A study on impact of AI-based Learning Tools on Self-Directed Learning (SDL) Skills amongst undergraduates

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Abstract:
As higher education continues to change, the way students interact with knowledge has been profoundly altered by the incorporation of Artificial Intelligence (AI) into learning environments. This study looked into how undergraduate students' development of self-directed learning (SDL) skills was affected by AI-based learning platforms like ChatGPT, Coursera, Napkin.AI, QuillBot, and Duolingo. SDL, which is defined by students' capacity to establish objectives, track their progress, manage resources, evaluate their learning, and maintain motivation, is becoming more and more important in the current digital education environment. Data was collected from a diverse sample of 220 undergraduate students across disciplines through a structured questionnaire. The study evaluated the frequency and efficacy of these AI tools' use as well as the degree to which they enhance fundamental SDL abilities like self-motivation, goal-setting, time management, resource utilization, and self-monitoring.
Quantitative analysis revealed a positive correlation between regular use of AI tools and higher levels of SDL readiness. Qualitative insights further highlighted that personalized feedback, instant access to information and gamified learning elements enhance learner autonomy and reflection.
The findings suggested that AI-based tools hold significant potential in fostering independent learning behaviors, provided that students are guided on optimal usage. The study concluded that AI-based tools can effectively foster SDL when integrated with intentional pedagogical support, offering insights for educators aiming to enhance learner independence and engagement.
The study also concluded that AI-based learning tools, when used strategically, have the potential to enhance self-directed learning skills in undergraduate learners. However, the effectiveness of such tools depends on learners' awareness of how to leverage them appropriately and the presence of institutional support that promotes responsible and reflective tool usage.
In order to enhance academic performance and lifetime learning competencies, the study suggested that educational institutions use AI responsibly and help students develop their capacity for self-regulation.
[***Keywords***: AI tools, SDL Skills, Feedback, Autonomy, Academic Support etc.]

1. Introduction:

Education is not an exception to the ways that the introduction of artificial intelligence (AI) has transformed other industries. Because they provide individualized, flexible, and data-driven learning experiences, AI-based learning technologies have become more and more popular in higher education in recent years. Tools that allow for real-time feedback, personalized pace, and interactive problem-solving, such ChatGPT, Coursera, Napkin.AI, QuillBot and Duolingo, have become essential to how students engage with educational information. Students' roles as passive information consumers are being transformed by these tools into active participants in their own learning process. Simultaneously, the capacity for autonomous learning, also known as self-directed learning (SDL), has become a crucial skill in the knowledge economy of the twenty-first century. SDL entails a learner's proactive participation in goal-setting, resource identification, time management, progress tracking, and outcome reflection.

SDL skills are becoming necessary for academic and professional success due to the growing emphasis on flexible learning settings and lifelong learning, especially in higher education. There is currently no empirical data on how AI-based learning tools actually affect students' capacity for self-directed learning, especially at the undergraduate level, despite their claims to promote autonomy and individualized learning. Without thoroughly analyzing how these tools impact particular aspects of self-directed learning, such as goal-setting, time management, self-monitoring, resource consumption, and intrinsic motivation, the majority of current research tends to concentrate on learning outcomes or satisfaction levels. By methodically investigating the effects of AI-based learning resources on undergraduate students' SDL abilities, this study seeks to close this gap. By analyzing both the extent and manner of AI tool usage and its relationship with self-directed learning behaviors, the study seeks to provide actionable insights for educators, instructional designers, and policy-makers striving to create more effective learner-centered digital environments.

2. Review of Literature:

- The study by **Shikina (2025)** demonstrates how artificial intelligence (AI) tools could revolutionize Uzbek students' motivation, autonomy, and self-directed learning. It notes that although empirical research in the Uzbek context is lacking, studies conducted worldwide have demonstrated the potential of technologies like chatbots, intelligent tutoring systems, and adaptive learning platforms to foster independent learning, higher-order thinking, and the development of metacognitive abilities. The shift to learner-centered approaches is aided by these resources. Ongoing issues including fair access, digital readiness, and the significance of culturally appropriate solutions are also mentioned in the study. Shikina emphasizes the need for further local research and focused policy initiatives while drawing the conclusion that, with careful application, AI can enable students to assume greater responsibility for their education and bring about significant educational transformation in Uzbekistan. (Shikina, 2025)
- The study by **Zhou (2025)** synthesizes empirical research to investigate how AI applications facilitate self-regulated learning (SRL) in higher education. The review shows that AI can support all three SRL phases forethought, performance, and reflection based on 14 studies that use tools including chatbots, adaptive feedback systems, serious games, and e-textbooks. Although these benefits are not consistent students with lower self-efficacy occasionally find it difficult to use AI tools effectively, and those who are less accustomed to digital technologies may see lower engagement positive outcomes include

increased learner autonomy, timely feedback, and improved motivation and self-efficacy. The paper makes a distinction between SRL's human-centered and AI-centered agency, pointing out that the ratio of these two factors has a variety of effects on student outcomes. Crucially, the authors emphasize that careful, balanced AI integration is required to guarantee that technological benefits are realized without compromising students' emotional or self-efficacy. They also urge more research to maximize the benefits of AI and self-regulated learning strategies in higher education. (Zhou, 2025)

- The study by **Mazari (2025)** explores how AI tools can improve higher education students' metacognitive skills. The study assesses a variety of AI solutions, including intelligent tutoring systems, adaptive learning environments, and even virtual and augmented reality experiences, using a rigorous methodology that includes surveys, interviews, and randomized controlled trials. The results show that successful metacognitive growth depends on a number of criteria, including strong student engagement, high-quality AI-generated feedback, and efficient alignment between AI tools and curriculum learning objectives. According to Mazari's analysis, AI can encourage more active reflection and adaptable learning strategies, which will ultimately improve learning, whereas traditional education frequently overlooks the direct development of metacognitive skills. The study does, however, also examine whether these benefits hold true in the absence of continuous AI assistance and stresses the significance of teachers carefully incorporating AI technologies to promote long-lasting metacognitive development. When taken as a whole, the study shows that carefully planned and integrated AI technologies can improve students' ability to learn independently and reflectively, enabling them to adjust to changing learning contexts more successfully. (Mazari, 2025)
- The study by **Chaoran Wang (2024)** discusses how self-directed learning (SDL) in postsecondary writing situations is being shaped by generative AI, particularly ChatGPT. It is based on an expanding body of research that demonstrates how AI technologies give students additional chances to privately discuss, produce ideas, edit, and consider their writing outside of the traditional classroom. Previous studies have demonstrated how ChatGPT and other similar tools may support a variety of writing tasks, such as idea generating, proofreading, and outlining, while encouraging students to use more active, self-regulated learning techniques. Key issues are also acknowledged in the literature, such as the conflict between maintaining authentic student voice and critical engagement while utilizing AI for efficiency, as well as practical and ethical worries about over-reliance or lost learning opportunities. In general, Wang et al.'s review summarizes previous research to show how AI is being incorporated more and more into self-directed learning practices. It also highlights the necessity for educators to encourage the moral, efficient, and critical use of these tools in the development of writing skills. (Chaoran Wang, 2024)
- The study by **Di Wu (2024)** summarizes recent studies on how generative AI is changing undergraduate education. According to the literature, interactive platforms powered by generative AI offer hitherto unheard-of possibilities for individualized and flexible instruction in higher education settings. Previous research highlights the importance of technological adoption, successful learning practices, and instructor assistance as key factors influencing self-directed learning (SDL). It has been discovered that using AI tools improves students' engagement with learning platforms and boosts their motivation and technological proficiency. Self-efficacy and learning motivation are highlighted as important mediating factors, where learners' autonomy, acceptance of technology, and academic self-confidence increase when supportive teaching and strategy deployment are improved in AI-enhanced

environments. By deepening our understanding of how generative AI may facilitate self-directed learning, this body of work informs the development of more efficient educational technologies and practices that encourage student autonomy and enhance learning outcomes in academic settings. (Di Wu, 2024)

- The study by **Behforouz & Ghaithi (2024)** examines the impact of interactive chatbots on self-directed learning by referencing a wide range of research on the use of conversational agents powered by artificial intelligence in educational contexts. Research continuously demonstrates that chatbots help self-directed learning by delivering personalized, in-the-moment feedback, enabling self-directed learning, and giving customized assistance that improves student engagement and academic performance. The examined literature demonstrates how chatbots are used in a variety of settings, such as language acquisition and programming, where they support motivation, the implementation of strategies, and active engagement. (Behforouz & Ghaithi, 2024)
- The study by **Pradhan (2024)** on how AI-based learning affects university students' motivation and study habits shows that AI tools are revolutionizing learning settings by encouraging drive, self-control, and individualized study strategies. According to studies, AI-powered systems can provide personalized feedback, adapt information to the needs of learners, and promote more active, involved learning practices. Students who use these tools frequently express increased motivation and happiness, pointing to the tools' adaptive features and learning progress tracking as major motivators. AI systems also facilitate strategic planning and efficient time management, encouraging routines like frequent review and in-depth interaction with the content. There are still issues, particularly with digital efficacy and fair access, but the evidence currently available indicates that integrating AI improves students' intrinsic motivation and fosters the growth of independent, reliable study habits, which eventually leads to better academic results. (Pradhan, 2024)
- The study by **Ekta Sharma (2024)** emphasises on the influence of artificial intelligence on teaching and learning processes is revolutionary, according to research that looks at AI tools in education from the viewpoints of both educators and learners. According to studies, chatbots, virtual tutors, and AI-driven grading systems promote student learning by providing immediate assignment evaluation, individualized guidance, and real-time feedback. These features encourage better academic achievement and increased engagement. Through data-driven decision-making and predictive analytics, AI helps educators by facilitating administrative efficiency, personalizing teaching materials, and enabling more focused interventions. Benefits including improved accessibility, customized learning pathways, and time savings are acknowledged by both groups. Nonetheless, worries about possible over-reliance on technology, moral dilemmas, data privacy, and the declining need of interpersonal communication continue. Although students value the ease and versatility of AI technologies, some educators are hesitant to replace conventional teaching techniques and emphasize the necessity for careful, moral integration of AI into educational practice to maximize its advantages while reducing related hazards. (Ekta Sharma, 2024)
- The study by **Zixi Li (2024)** emphasizes on Generative AI promoting increased learner autonomy, motivation, and flexibility in tailored learning, according to research on the usage of ChatGPT for self-directed online language learning. Because ChatGPT may customize content to match their interests, skill level, and objectives, learners are very motivated to use it, according to recent mixed-method studies that include survey data from 276 participants and interviews with 11 language learners. Strong

self-monitoring and self-directing abilities are essential for utilizing ChatGPT's capabilities and assisting users in successfully achieving their goals, according to key findings. The study emphasizes the platform's advantages in offering personalized content access, facilitating flexible learning paths, and providing instant feedback all of which improve independent study practices. Even though ChatGPT provides more learning opportunities and accommodates a range of educational demands, students' ability to self-regulate and actively manage their learning processes is crucial for these technologies to be used effectively. (Zixi Li, 2024)

- This study by **Kruger (2024)** highlights the expanding impact of AI chatbots in promoting student agency and self-directed learning (SDL) by examining them as open educational resources. Research shows that by providing individualized, flexible help and feedback, AI chatbots in educational environments enable students to take charge of their own learning paths. These chatbot systems democratize access to educational materials by giving students the freedom to establish personal objectives, track their progress, and choose their own learning trajectories. Additionally, research highlights that although chatbots help students become more independent, think critically, and be motivated, their integration must take into account issues like data protection, possible over-reliance, and guaranteeing fair access. The literature urges teachers to see AI chatbots as dynamic collaborators who enhance conventional teaching methods and make learner-centered, participatory education possible. All things considered, AI chatbots are positioned as a catalyst for more flexible, inclusive, and student-driven learning settings; yet, to fully realize their potential, careful deployment and continuous assessment are still essential. (Kruger, 2024)
- The study by **Dr. Kamma Ramanjaneyulu (2024)** on artificial intelligence's effects in education emphasize how important it is for improving institutional safety, student motivation, and decision-making. By facilitating data-driven decision-making, more accurate student evaluations, resource management, and individualized learning pathways, artificial intelligence (AI) solutions assist educators and administrators. In terms of motivation, AI-powered platforms offer personalized learning experiences, real-time feedback, and adaptable content, which boosts student engagement and lowers procrastination. Studies warn against becoming overly reliant on these technologies, though, as this can impair critical thinking skills and lower intrinsic drive. Furthermore, even while AI-based monitoring systems have increased campus safety and risk management, they also bring up serious issues with data privacy, surveillance, and ethical use. According to the literature, artificial intelligence (AI) has the potential to improve learning environments overall, but its application needs to be led by moral principles and careful integration to make sure that it enhances rather than undermines education's fundamental principles. (Dr. Kamma Ramanjaneyulu, 2024)
- The study by **Farhad. Namjoo (2023)** offers a thorough qualitative analysis of student interactions with AI-assisted self-study tools. The study finds five main themes through semi-structured interviews with 20 students from various academic backgrounds: learning results, assistance and resources, obstacles and limitations, engagement with AI tools, and general perspectives of AI in education. Students stated that the simplicity of use, interactive features, and customized learning experiences provided by AI technologies improved their learning and engagement. Notably, the main advantages were emphasized as being increases in knowledge retention, skill development, and the capacity to apply acquired concepts to actual issues. But the study also identifies important obstacles, such as

content constraints, technical problems, worries about data protection, and the need to accommodate different learning styles. (Farhad. Namjoo, 2023)

- This study by **Perkins** demonstrates how the field of self-directed learning (SDL) is changing as a result of generative artificial intelligence (GenAI). Four major themes emerge from the literature, according to the study by Jasper Roe and Mike Perkins: the promise for tailored learning experiences, the necessity of exercising prudence, the potential for GenAI to improve SDL, and the changing role of educators as GenAI mentors. The capacity of GenAI technologies, like ChatGPT and other large language models, to offer individualized, on-demand assistance that can enable students to take charge of their educational paths is emphasized. But the study also highlights how important teachers are, as their focus shifts to assisting students in developing vital AI literacy skills and utilizing AI technologies efficiently. There are enduring concerns regarding the accuracy of GenAI outputs, access equity, data privacy, and the need for additional longitudinal research to completely comprehend the long-term effects of these technologies on self-directed learning outcomes, despite the obvious promise of personalized learning pathways and enhanced accessibility. According to the findings, GenAI should be carefully and contextually integrated into education to balance the benefits of technology with fundamental pedagogical principles. (Perkins)

3. Research Methodology:

3.1 Research Objectives:

- To identify the association between **gender** and **frequency of use** of the AI-based tools
- To examine the frequency and patterns of AI-based learning tool usage among undergraduates
- To assess the influence of AI tools on key self-directed learning (SDL) skills
- To explore students' experiences and personal reflections on how AI tools contribute to their self-directed learning process and recommend about improving the efficiency of it

3.2 Research Design: To investigate the connection between undergraduate students' development of self-directed learning (SDL) skills and their use of AI-based learning aids, this study used a quantitative, descriptive, and correlational research approach. In order to enhance interpretive insights, the study also included qualitative inputs in the form of open-ended questions.

3.3 Sample Size: The target population comprised undergraduate students from various academic years and specialties. To guarantee proportionate representation of students from different programs (B.A., B.Sc., B.Com., and B.Tech/B.E.), a stratified random sampling technique was employed. In order to guarantee the validity and generalizability of the results, the study sought to gather answers from at least 200 students.

3.4 Research Instrument: A structured questionnaire was developed based on literature and adapted from validated tools such as the **Self-Directed Learning Readiness Scale (SDLRS)**. The questionnaire was divided into five sections:

Section	Purpose	Variables Measured

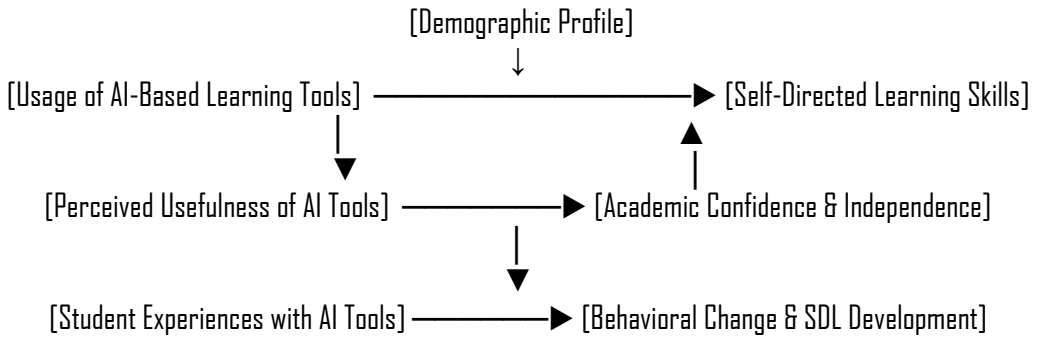
A: Demographic Information	Understand student background	Age, Gender, Program, Year, Institution Type
B: AI Tool Usage	Measure frequency and types of AI tools used	ChatGPT, Napkin.AI, Coursera, Quillbot and Duolingo
C: SDL Skills	Assess self-directed learning competencies	Goal-setting, Self-monitoring, Time management, Resource management, and Persistence
D: Perceived Impact	Examine students' perceptions of AI impact	Independence, Confidence, Academic performance and Complementarity
E: Open-Ended	Gather qualitative experiences	Usefulness of tools and SDL transformation instances

A 5-point Likert scale was used to collect responses in Sections B, C, and D. The range of values was 1 = Strongly Disagree to 5 = Strongly Agree (or 1 = Never to 5 = Very Often in Section B).

3.5 Variables and Conceptual Framework: Based on the study objectives and hypotheses, the conceptual framework established the following variable relationships:

Type	Variable
Independent Variable:	Frequency and type of AI-based learning tool usage
Dependent Variable:	Rating of self-directed learning skills
Moderating Variables:	Demographic profile: Age, Gender, Year, Programme
Mediating Variables:	Perceived usefulness, confidence, motivation
Qualitative Indicators:	Real-world learning behavior change and student reflections

The following is an image representation of the conceptual framework:



3.6 Data Collection Procedure:

- The questionnaire was administered via Google Forms and shared through institutional channels and student groups.
- A brief description of the research along with consent information was provided at the beginning of the form.

3.7 Data Analysis Techniques:

- **Chi-Square Analysis** was used to analyze demographic data (gender) and usage patterns.
- **Pearson's correlation** was applied to examine relationships between AI tool usage and SDL skills.
- **Qualitative data** from open-ended questions were analyzed using thematic coding to identify recurring patterns and narratives.

3.8 Ethical Considerations:

- Participants were informed of the voluntary and anonymous nature of the study.
- Data was securely stored and used solely for academic research purposes.

4. Data Analysis and Interpretation:

4.1 Hypothesis:

Research Hypothesis (H1)	Null Hypothesis (H0)
There is a significant association between undergraduates' gender and their usage of AI-based learning tools.	There is no significant association between undergraduates' gender and their usage of AI-based learning tools.
There is a statistically significant positive impact of AI-based learning tools on students' self-directed learning skills (goal setting, time management, self-monitoring and reflection, resource management, persistence).	AI-based learning tools have no significant impact on students' self-directed learning skills.
Students' qualitative experiences suggest that AI-based tools significantly enhance SDL efficiency and indicate areas for improvement.	Students' qualitative experiences do not suggest that AI-based tools significantly enhance SDL efficiency or provide meaningful suggestions for improvement.

4.2 Analysis and interpretation using statistical tests:

4.2.1 Gender & Frequency of use of AI tools

Observed:

Gender	ChatGPT	Napkin.AI	Coursera	Quillbot / GrammarlyGo	Duolingo	Total
Male	12	3	7	7	3	32
Female	66	24	37	36	38	201
Total	**78**	**27**	**44**	**43**	**41**	**233**

Expected:

Gender	ChatGPT	Napkin.AI	Coursera	Quillbot/GrammarlyGo	Duolingo	Total
Male	11	4	6	6	6	32
Female	67	23	38	37	35	201
Total	**78**	**27**	**44**	**43**	**41**	**233**

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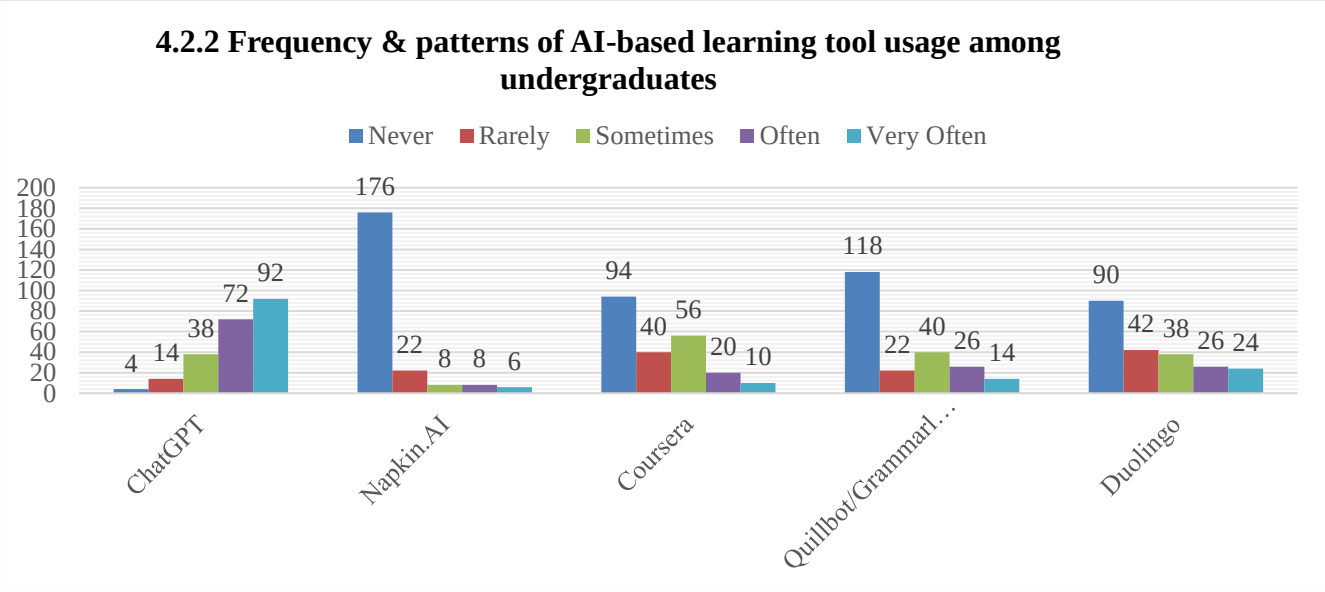

4.2.3 Correlation Table	GS	SM & Rf	TM	RM	PS	Chat GPT	Napkin. AI	Coursera	Quillbot / Grammarly Go	Duolingo
GS	1									
SM & Rf	0.67	1								
TM	0.53	0.66	1							
RM	0.52	0.48	0.26	1						
PS	0.48	0.63	0.5	0.53	1					
Chat GPT	0.49	0.61	0.46	0.49	0.6	1				
Napkin.AI	0	0.1	0.18	-0.02	-0.04	0.07	1			
Coursera	0.16	0.23	0.25	0.31	0.13	0.16	0.21	1		
Quillbot / Grammarly Go	0.26	0.29	0.3	0.28	0.16	0.21	0.57	0.3	1	
Duolingo	0.15	0.11	0	0.12	-0.05	-0.02	0.32	0.31	0.29	1

GS: Goal Setting SM & Rf: Self-Monitoring & Reflection TM: Time Management
RM: Resource Management PS: Persistence

➢ Correlation within SDL Skills:

High Interconnection: Strong and moderate positive correlations (r = 0.49 to 0.67) were observed between all SDL skills.

Improving one SDL skill (like goal setting or reflection) is likely to enhance others (like time management and persistence).

Self-Directed Learning (SDL) skills are **highly interrelated**, suggesting that development in one area can positively influence others.

➢ AI Tools and Their Impact on SDL Skills:

ChatGPT

- Shows the **strongest and most consistent** positive correlations with all SDL skills.
- Most notable in **self-monitoring (r = 0.61)** and **persistence (r = 0.60)**.

ChatGPT is **highly effective** in supporting and enhancing students' SDL skills.

Napkin.AI

- All correlations are weak or negligible.
- Some weak **negative** correlations, e.g., persistence (r = –0.05).

Napkin.AI shows **minimal to no meaningful impact** on SDL development.

Coursera

- Moderate correlation with **resource management (r = 0.31)**.
- Weak to moderate for **time management and other SDL skills**.

Coursera provides **moderate support**, especially in accessing academic resources.

Quillbot/GrammarlyGO

- Moderate correlations in **time management (r = 0.30)** and **resource management (r = 0.28)**.
- Supports goal clarity and study organization.

Helpful for **structuring learning and improving clarity** in academic tasks.

Duolingo

- All correlations are very weak or negative.
- No relationship with time management or persistence.

Duolingo has **minimal association** with broader SDL skills.

4.2.4

AI Tools / SDL Skills	ChatGPT	Napkin.AI	Coursera	Quillbot / GrammarlyGO	Duolingo
Goal Setting [SDL 1]	0.49	0.00	0.16	0.26	0.15
Self-Monitoring & Reflection [SDL 2]	0.61	0.1	0.24	0.29	0.11
Time Management [SDL 3]	0.47	0.18	0.25	0.3	0
Resource Management [SDL 4]	0.49	-0.03	0.31	0.28	0.12

Persistence [SDL 5]	0.60	-0.05	0.14	0.16	-0.05

ChatGPT:

Shows **consistently strong positive correlations** across all SDL components (especially *Self-Monitoring* and *Persistence*).

Strongest correlation: SDL 2 - Self-Monitoring & Reflection [0.61]
SDL 5 – Persistence [0.60]

Indicates ChatGPT is widely perceived as a helpful AI tool for self-directed learning.

***Napkin.AI*:**

Exhibits **very weak to negative correlations** across all SDL components.

Slightly positive for SDL 3 - Time Management [0.18], but negative for SDL 4 and SDL 5.

Indicates **limited or less effective** perceived role in enhancing SDL skills.

Coursera:

Shows **moderate positive correlations**, especially for: SDL4 - Resource Management [0.31]
SDL3 - Time Management [0.25]

Suggests Coursera supports structured learning and resource discovery.

Quillbot / GrammarlyGO:

Moderate correlations across SDL skills, highest with: SDL 3 - Time Management [0.30]
SDL 2 - Self-Monitoring [0.29]

Reflects it's helpful in improving writing, feedback and structured study habits.

Duolingo:

Low or near-zero correlations, even slightly negative in: SDL 5 - Persistence [–0.05]
SDL 1 - Goal Setting [0.15]

Suggests Duolingo does not contribute significantly to core SDL skills outside language learning.

5. Findings & Conclusion:

5.1

Chi-square Statistic: 2.17
Degrees of Freedom (df): 4
P-value: 0.704
Interpretation: Since the **p-value (0.704)** is **greater than 0.05**, we **fail to reject the null hypothesis**.
There is **no statistically significant association** between **gender** and **frequency of use** of the AI-based tools (ChatGPT, Napkin.AI, Coursera, Quillbot/GrammarlyGo, Duolingo) for academic learning.

5.2

ChatGPT stands out as the primary AI learning assistant in frequent and consistent use. ChatGPT is the most frequently and widely adopted tool among undergraduates. Its versatility and accessibility likely contribute to its popularity.

Most other tools are **either rarely used or used situationally**. Napkin.AI is either unfamiliar to most students, lacks perceived utility or is less relevant to undergraduate academic tasks. While Coursera is recognized and sometimes used, it isn't part of students' regular learning habits, possibly due to time commitment or course format. These tools may be used more situationally (e.g., for writing tasks) rather than as core learning platforms. Duolingo appeals to a niche group of language learners but is not broadly used across disciplines.

5.3

The data suggests a **heavy skew toward one dominant AI tool (ChatGPT)**, with others lagging significantly behind.

- **Most Impactful Tool: ChatGPT,** due to strong and consistent correlations with all SDL skills.
- **Moderately Effective Tools: Coursera** and **Quillbot / GrammarlyGO** for structured study and resources.
- **Least Effective Tools: Napkin.AI** and **Duolingo,** with negligible or no impact.

5.4

From the correlation results and qualitative feedback:

- Undergraduates **positively associate** ChatGPT and similar tools with goal setting, reflection, time management, and persistence.
- AI tools - Napkin.AI and Duolingo show **low or negligible usefulness**, due to limited interactivity or relevance to academic learning.
- SDL skills are **mutually reinforcing** suggesting that a holistic learning experience can strengthen all dimensions when supported by the right tools.

6. Suggestions & Recommendations:

➢ **To improve the efficiency of AI in self-directed learning:**

- **Scale up the use of proven tools** like ChatGPT with structured strategies.
- Use **ChatGPT** as a **central AI tool** to foster SDL capabilities.
- **Redesign or reposition less impactful tools** based on SDL needs.
- Combine it with **Coursera** and **Quillbot** to support resource use and time structuring.
- **Equip undergraduates and teachers** with guidance, digital literacy and ethical AI usage practices.
- **Promote holistic growth** by addressing all SDL components, as they are interlinked.

➢ **Maximize Effective AI Tool Usage:**

a. Encourage Structured Use of ChatGPT for SDL:

- **Goal Setting Templates:** Promote the use of ChatGPT to generate structured weekly/monthly academic goals.
- **Prompt Libraries:** Create academic prompt banks to guide undergraduates in generating meaningful self-reflection and study schedules.
- **Reflection Aids:** Use ChatGPT to simulate self-assessment questions after learning sessions.

b. Enhance Use of Quillbot / GrammarlyGO for Clarity and Resource Management:

- Encourage usage for paraphrasing and summarizing complex topics.
- Promote their role in draft refinement, leading to better clarity in writing and time efficiency.

c. Implications for AI-based Learning Adoption:

- Institutions aiming to integrate AI in learning might **leverage ChatGPT as a starting point** due to its established user base.
- There's a need for **awareness and onboarding** for underutilized tools like Napkin.AI or Coursera.
- **Tool utility, accessibility and relevance** to academic needs strongly influence student adoption.

➢ **Improvement in SDL Skills via AI Integration**

a. Reflection & Monitoring Workshops:

- Host guided workshops where undergraduates reflect on their learning using AI tools.
- Teach undergraduates how to evaluate feedback given by AI critically.

b. Self-Tracking Systems:

- Introduce AI-integrated tools (like Notion + ChatGPT) to track SDL progress over time with built-in self-monitoring checkpoints.

- **Institutional & Pedagogical Recommendations**

Embed AI Use in Academic Curriculum:

- Assign structured AI-based tasks (e.g., using ChatGPT to create revision guides or reflect on lectures).
- Assess SDL skill growth through AI-aided assignments.

Faculty Training & AI-Awareness:

- Conduct faculty development programs on AI tools' role in SDL.
- Train instructors to guide students on productive AI use vs. overdependence.

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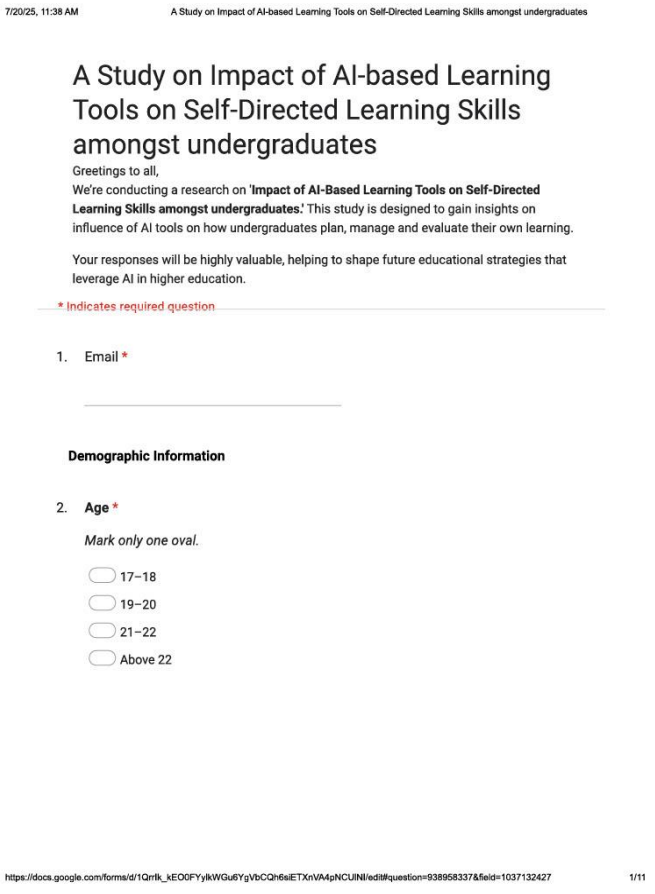
8. Appendices:



7/20/25, 11:38 AM A Study on Impact of AI-based Learning Tools on Self-Directed Learning Skills amongst undergraduates

A Study on Impact of AI-based Learning Tools on Self-Directed Learning Skills amongst undergraduates

Greetings to all,
We're conducting a research on **'Impact of AI-Based Learning Tools on Self-Directed Learning Skills amongst undergraduates.'** This study is designed to gain insights on influence of AI tools on how undergraduates plan, manage and evaluate their own learning.

Your responses will be highly valuable, helping to shape future educational strategies that leverage AI in higher education.

* Indicates required question

1. Email *

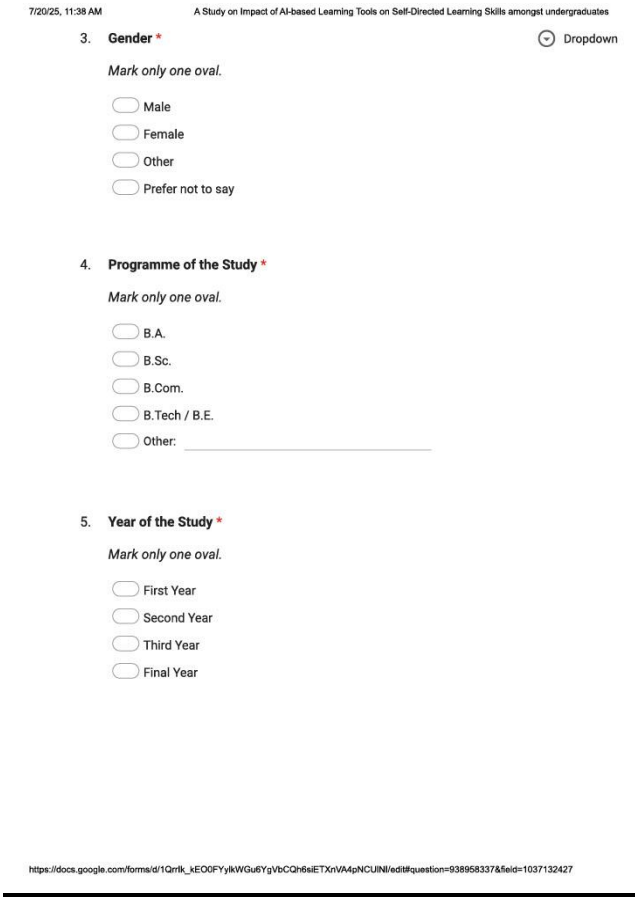
Demographic Information

2. **Age** *

Mark only one oval.

- 17–18
- 19–20
- 21–22
- Above 22

https://docs.google.com/forms/d/1Qrrlk_kEO0FYylkWGu6YgVbCQh6siETXnVA4pNCUINI/edit#question=938958337&field=1037132427 1/11



7/20/25, 11:38 AM A Study on Impact of AI-based Learning Tools on Self-Directed Learning Skills amongst undergraduates

3. **Gender** * Dropdown

Mark only one oval.

- Male
- Female
- Other
- Prefer not to say

4. **Programme of the Study** *

Mark only one oval.

- B.A.
- B.Sc.
- B.Com.
- B.Tech / B.E.
- Other:

5. **Year of the Study** *

Mark only one oval.

- First Year
- Second Year
- Third Year
- Final Year

https://docs.google.com/forms/d/1Qrrlk_kEO0FYylkWGu6YgVbCQh6siETXnVA4pNCUINI/edit#question=938958337&field=1037132427 2/11

6. **Type of the Institution** *

Mark only one oval.

- ◯ Government
- ◯ Private
- ◯ Autonomous

Usage of AI-Based Learning Tools & the impact on Self-Directed Learning Skills (SDLs)

AI based tools considered under the study:-

1. ChatGPT (Open AI)
2. Napkin.AI
3. Coursera
4. Quillbot / GrammarlyGo
5. Duolingo

Self-Directed Learning Skills (SDLs) considered under the study:-

1. Goal Setting
2. Self-monitoring & Reflection
3. Time Management
4. Resource Management
5. Persistence

7. **Please indicate how frequently you use the following AI-based tools for academic learning purposes.** *
(Scale: 1 = Never | 2 = Rarely | 3 = Sometimes | 4 = Often | 5 = Very Often)

Mark only one oval per row.

	1	2	3	4	5
ChatGPT (OpenAI)	◯	◯	◯	◯	◯
Napkin.AI	◯	◯	◯	◯	◯
Coursera	◯	◯	◯	◯	◯
Quillbot / GrammarlyGO	◯	◯	◯	◯	◯
Duolingo	◯	◯	◯	◯	◯

8. **SDL 1:- Goal Setting** *

Mark only one oval per row.

	1	2	3	4	5
I set clear academic goals for myself.	◯	◯	◯	◯	◯
AI tools help me define learning goals more effectively.	◯	◯	◯	◯	◯
I can break down large learning objectives into smaller achievable goals using AI tools.	◯	◯	◯	◯	◯

9. **SDL 2:- Self-Monitoring & Reflection** *

Mark only one oval per row.

	1	2	3	4	5
I regularly track my academic progress.	◯	◯	◯	◯	◯
AI tools give me feedback that helps in self-reflection.	◯	◯	◯	◯	◯
I use AI-based feedback to improve my learning process.	◯	◯	◯	◯	◯

10. **SDL 3:- Time Management** *

Mark only one oval per row.

	1	2	3	4	5
I am able to manage my study time efficiently.	◯	◯	◯	◯	◯
AI tools help me plan and prioritize my learning tasks.	◯	◯	◯	◯	◯
I follow a structured study schedule with the help of AI tools.	◯	◯	◯	◯	◯

11. **SDL 4:- Resource Management** *

Mark only one oval per row.

	1	2	3	4	5
I know where to find academic resources for my study.	◯	◯	◯	◯	◯
AI tools help me discover and use a wider range of academic resources.	◯	◯	◯	◯	◯
I compare multiple sources using AI tools before accepting any information.	◯	◯	◯	◯	◯

12. **SDL 5:- Persistence** *

Mark only one oval per row.

	1	2	3	4	5
I continue working on academic tasks even when they are challenging.	◯	◯	◯	◯	◯
AI tools encourage me to not give up when I face learning difficulties.	◯	◯	◯	◯	◯
I use AI tools to try alternative learning methods when I don't understand a topic.	◯	◯	◯	◯	◯

13. **Please rate the following statements:** *
(Scale: 1 = Strongly Disagree | 2 = Disagree | 3 = Neutral | 4 = Agree | 5 = Strongly Agree)

Mark only one oval per row.

	1	2	3	4	5
AI tools have made me more independent in my learning.	◯	◯	◯	◯	◯
AI tools help me adapt to my learning process according to my pace.	◯	◯	◯	◯	◯
My academic performance has improved since using AI tools.	◯	◯	◯	◯	◯
I feel more confident about learning new topics using AI tools.	◯	◯	◯	◯	◯
AI tools complement traditional teaching methods effectively.	◯	◯	◯	◯	◯

14. **Which AI-based learning tool do you find most useful and why?**

15. **Can you describe a situation where an AI tool helped you become more self-directed in your learning?**

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Using AI and Machine Learning to Improve Teaching Skills Through Faculty Development Programs in Higher Education Institutions

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ABSTRACT

In higher education institutions, Faculty Development Programs (FDPs) are essential for improving the caliber of instruction and encouraging ongoing professional development. However, the overall benefit of typical FDPs on enhancing teaching abilities is limited since they frequently lack customization, real-time feedback, and flexibility. The incorporation of Artificial Intelligence (AI) and Machine Learning (ML) into faculty training offers a substantial chance to get beyond these constraints and update educator development in the era of digital transformation. In order to enhance faculty members' teaching abilities, this study investigates the application of AI and ML technologies in FDPs. It explores the creation of individualized and captivating development experiences via the use of intelligent technologies including automated feedback systems, predictive analytics, and adaptive learning platforms. Using a mixed-method approach, the study combines survey data with interviews with administrators and academics at certain universities. Results show that FDPs augmented by AI and ML provide a number of benefits, such as personalized learning pathways, better engagement, data-driven progress monitoring, and more efficient instructional strategies. But the report also points out important issues including infrastructural constraints, reluctance to technology use, and gaps in digital literacy. The study ends with suggestions for incorporating AI and ML into faculty development plans, stressing the value of training assistance, institutional preparedness, and ethical data usage. This study adds insightful information to the body of knowledge on educational technology and offers a useful foundation for universities looking to integrate AI and ML into their faculty development initiatives.

KEYWORDS

Artificial Intelligence, Instructional Proficiency, EdTech Integration , Machine Learning, Pedagogical Advancement, Educator Competency, Technological Infusion

INTRODUCTION

Effective teaching is essential to improving student learning outcomes and institutional success in the quickly changing world of higher education. Faculty Development Programs (FDPs) have long been essential in providing teachers with the most up-to-date pedagogical knowledge, subject-matter competence, and instructional techniques. However, the long-term effects of traditional FDPs on faculty teaching abilities are limited since they frequently adhere to strict forms, lack customization, and do not offer real-time feedback.

Simultaneously, the development of machine learning (ML) and artificial intelligence (AI) has revolutionized a number of industries, including education. Through the provision of tailored, flexible, and data-driven learning experiences that complement individual teaching requirements, these intelligent technologies have the potential to completely transform faculty development. There is little empirical study on how AI and ML are incorporated into faculty development procedures in higher education institutions, despite the increased interest in EdTech advances. The main issue is figuring out how to best use these cutting-edge technology to improve teaching abilities and what obstacles stand in the way of their uptake. In a time when educational institutions aim to match teaching quality with global standards and technological breakthroughs, filling this research gap is essential. Examining the function and efficacy of AI and ML in faculty development initiatives meant to enhance teaching abilities in higher education institutions is the main goal of this study. The study's specific objectives are to evaluate existing procedures, investigate AI/ML applications in training materials, and pinpoint implementation's results and difficulties. In order to do this, the study aims to respond to the following queries:

1. How are faculty development programs now utilizing AI and ML?
2. How do these technologies affect the efficacy of instruction?
3. What are the primary factors facilitating and impeding their integration?

This study is important because it offers up-to-date information on how academic growth frameworks might strategically include intelligent technology. By providing evidence-based suggestions for creating tech-enabled professional development programs that support instructional excellence, the findings will assist academic trainers, legislators, and institutional leaders. The paper's structure is set out as follows: A survey of the body of research on faculty development and AI/ML in education is given in the next section. The research methodology, which describes the design, data gathering strategies, and analytic procedures, comes next. The conclusions, interpretation of the findings, and practical consequences are covered in the following sections. Recommendations, constraints, and future study directions are discussed in the paper's conclusion.

LITERATURE REVIEW

Over the past 10 years, there has been an increase in interest in integrating AI and ML into educational settings, with an emphasis on enhancing learning outcomes, instructional design, and administrative procedures. However, a large portion of the research now in publication focuses on applications that are targeted at students, such automated assessment tools, intelligent tutoring systems, and individualized learning. In contrast, there is still a lack of research on the use of AI and ML to promote faculty development, especially in the area of teaching skill improvement.

Faculty Development Programs (FDPs) are widely acknowledged as crucial tools for professional development, allowing teachers to embrace new technology, update their pedagogical approaches, and increase the efficacy of their instruction (Guskey, 2002; Steinert et al., 2006). The design of such programs has long been influenced by theories that emphasize learner-centered methods, self-direction, and reflection, such as the Experiential Learning Theory (Kolb, 1984) and the Adult Learning Theory (Knowles, 1980). However, these frameworks lack real-time feedback and technical adaptation, two things that AI and ML are very good at. Recent research has started to investigate how AI-based solutions, such intelligent analytics and adaptive learning platforms, might help educators customize their professional development (Luckin et al., 2016; Holmes et al., 2019).

Machine learning algorithms are able to evaluate performance data, spot gaps, and suggest focused actions. Despite these developments, there are few empirical studies that concentrate on FDPs in higher education that are especially boosted by AI and ML. The majority of research that is now accessible is either theoretical or restricted to pilot studies in institutions with high technology, sometimes ignoring real-world limitations in underdeveloped nations.

This highlights a significant vacuum in the literature: there aren't enough thorough, situation-specific studies on how AI and ML might be methodically incorporated into faculty development initiatives to enhance teaching abilities. Furthermore, little is known about the success factors (like institutional support and infrastructural preparation) and obstacles (like digital literacy, resistance to change, and ethical issues) associated with this integration. The current study is based on the TPACK Framework (Technological Pedagogical Content Knowledge) and the Technology Acceptance Model in order to close this gap. While TPACK offers a comprehensive perspective on how technology, pedagogy, and topic knowledge intersect to promote effective teaching, TAM provides insight into faculty attitudes and readiness to use AI-driven systems.

This conceptual underpinning encourages research into AI and ML as essential parts of a dynamic, adaptable faculty development environment, rather than just as tools. The research aims to provide a fresh viewpoint on modernizing faculty development using intelligent systems by combining knowledge from learning theory, educational technology, and organizational transformation.

RESEARCH METHODOLOGY

In order to give a thorough grasp of how AI and machine learning are being incorporated into faculty development programs and their effects on teaching efficacy, this study uses a mixed-methods research design, integrating quantitative and qualitative techniques. Triangulation of data is made possible by the mixed-method design, which guarantees increased validity and deeper insights into the execution and results of professional development programs in higher education that are enabled by AI and ML.

Semi-structured interviews and structured questionnaires were the two main techniques used to collect data. The purpose of the questionnaire was to gather quantitative information on institutional preparedness, faculty perspectives, use trends, and the efficacy of AI/ML technologies. A 5-point Likert scale was used in its development to gauge factors including user-friendliness, educational effectiveness, and engagement. To get qualitative information on the experiences, difficulties, and expectations of academic administrators, IT specialists, and a select group of faculty members about the incorporation of AI and ML in faculty training, semi-structured interviews were performed with these individuals concurrently.

Faculty members from several higher education institutions in Rajasthan, India, make up the study's target population. A sample of 100 faculty members who had taken part in traditional or technology-enhanced faculty development programs was chosen using a purposive sampling approach. In order to learn about institutional viewpoints and technological integration tactics, ten administrators and academic leaders were also interviewed. In order to find patterns, correlations, and the effect of utilizing AI/ML to improve teaching skills, the quantitative data collected from the questionnaires was subjected to regression analysis, correlation analysis, and descriptive statistics using SPSS software.

Thematic analysis of the qualitative interview data enabled the discovery of recurrent themes, insights, and contextual interpretations that explain the factors that support and hinder the integration of AI/ML in FDPs. Regarding ethical issues, the study guaranteed each respondent's privacy, informed permission, and voluntary participation. The goal of the study and how their data will be used were explained to the participants in detail. Before data collection started, the study obtained the necessary institutional approval and complied with academic inquiry ethics.

RESULT

The following tables summarizes the survey's findings about the Using AI and Machine Learning to Improve Teaching Skills Through Faculty Development Programs in Higher Education Institutions.

S.NO.	Research Focus Area	Findings	% of Respondents
1	Awareness of AI/ML in FDPs	Faculty members were aware of AI/ML-based tools in development programs	78%
2	Participation in AI/ML-enabled FDPs	Faculty had attended at least one AI- or ML-supported faculty development session	68%
3	Perceived improvement in teaching skills	Participants reported improvement in classroom engagement, teaching techniques, and tech integration	61%
4	Usefulness of AI tools in FDPs	Tools like content recommenders, feedback systems, and simulations were rated useful	73%
5	Key benefits observed	Personalized learning, real-time feedback, self-paced training, improved digital pedagogy	-
6	Major challenges faced	Low digital literacy, infrastructure issues, resistance to change, lack of AI training	-
7	Institutional support availability	Faculty received technical and administrative support for AI tool usage in FDPs	52%
8	Preference for hybrid training model	Faculty and administrators preferred combining AI-based tools with traditional mentoring	81%
9	Openness to future AI-based FDPs	Willingness to engage in AI/ML-integrated faculty development in the future	85%

Table No.1 Empirical Findings on AI and ML Integration in Faculty Development Programs

SUGGESTION

Several practical recommendations may be made to improve the incorporation of AI and ML into faculty development programs at higher education institutions based on the study's findings. First and foremost,

educational institutions have to give top priority to implementing AI-powered systems that provide faculty members with individualized and flexible learning opportunities. In order to make professional development more efficient and pertinent, these platforms ought to be made to accommodate a variety of teaching philosophies, topic areas, and ability levels.

Second, to guarantee that teachers—particularly those with little experience to technology—are at ease utilizing AI technologies, extensive digital literacy training has to be incorporated into faculty development programs. Faculty confidence and proficiency may be increased through workshops and orientation programs that emphasize the real-world application of machine learning (ML)-driven classroom simulations, content recommendation engines, and performance analytics.

Institutions have to think about adopting a hybrid faculty development strategy that combines peer cooperation and human mentorship with AI-powered self-paced courses. While maintaining the personal connection that many instructors cherish, this hybrid method can optimize learning results.

Institutional policy frameworks are also required to direct the moral use of AI in professional growth. These have to include explicit data privacy procedures, openness in AI suggestions, and precautions against relying too much on automated systems. Working together with EdTech companies and AI specialists can also aid in creating context-specific solutions that are suited to faculty requirements and institutional objectives. Lastly, to determine how AI-integrated faculty development programs affect teaching effectiveness, continuous monitoring and evaluation systems should be put in place. Participants' regular input should guide such programs' ongoing development and expansion.

CONCLUSION

The way higher education institutions may support and improve teaching abilities has changed significantly with the introduction of Artificial Intelligence (AI) and Machine Learning (ML) into faculty development programs. By providing individualized, flexible, and data-driven learning experiences that cater to the particular requirements of each educator, this study has demonstrated how AI and ML have the potential to revolutionize conventional faculty development approaches. According to the results, faculty members who used AI-enabled development tools reported better teaching methods, more classroom participation, and a deeper comprehension of educational technology.

But the survey also found a number of obstacles to successful adoption, such as a lack of digital literacy, inadequate infrastructure, and reluctance to embrace new technology. These difficulties show that although implementing AI and ML has potential, it needs to be done carefully, taking ethical issues, institutional backing, and proper training into account. To make sure that these programs are not only successful but also long-lasting and inclusive, academic leadership, policy creation, and ongoing oversight play a critical role.

To sum up, AI and ML have the potential to greatly improve the caliber and effectiveness of faculty development programs, which will increase pedagogical creativity and improve teaching results. Higher education institutions may cultivate a culture of ongoing learning and instructional excellence by integrating these technologies within a human-centered, well-structured framework. This study adds to the expanding body of knowledge on educational technology and provides useful advice for responsibly and meaningfully incorporating intelligent technologies into professional development.

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FaceTrack: CNN-Based Facial Emotion Recognition for Stress Monitoring in Sports Physiology

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Abstract

We present FaceTrack, an efficient convolutional neural network (CNN) model developed for real-time detection of facial emotions, specifically geared toward monitoring stress in athletes during both training and rehabilitation phases. Trained on the FER-2013 dataset, which includes 35,887 grayscale images of size 48×48 pixels representing seven emotional categories, the model attained an impressive test accuracy of 92.39%. It outperformed several existing approaches in terms of both accuracy and computational efficiency. The model demonstrated particularly high accuracy in recognizing "happy" and "neutral" emotions, while slightly lower results were noted for "fear" and "surprise." Thanks to its lightweight architecture, FaceTrack is well-suited for deployment on edge devices such as smartphones and wearables, offering a practical solution for use in fields like sports psychology and physiotherapy. The complete implementation is available for public access at:

- GitHub: https://github.com/SaravagiDeepika/Stress-Recognition
- Kaggle: https://www.kaggle.com/code/drdeepikasaravagi/stress-recognition

Keywords: facial emotion recognition; CNN; FER-2013; stress detection; sports physiology; wearable systems

1. Introduction

Facial expressions, particularly those linked to stress, often reflect an individual's emotional state during physical exertion and recovery. Traditional evaluation methods—such as subjective athlete feedback or observational assessments—tend to lack consistency and are often delayed in response. In this context, we introduce **FaceTrack**, an intelligent facial emotion recognition tool designed to provide real-time, objective insights into stress levels through integration with mobile and wearable platforms. As affective computing continues to play an expanding role in health and performance analytics, FaceTrack emerges as a relevant and practical solution.

Research Objectives:

- To design a compact and efficient CNN architecture capable of detecting facial emotions in real time, optimized for use on mobile and edge devices.
- To evaluate the model's practical utility in tracking emotional stress during sports training and rehabilitation.
- To examine and mitigate the effects of imbalanced emotion categories within the training data.
- To compare the proposed system's accuracy and performance with current facial emotion recognition techniques.

- To validate the model's suitability for domain-specific applications through experimental testing and analysis.

2. Literature Review: Facial Emotion Recognition

Facial Emotion Recognition (FER) has undergone notable progress with the integration of deep learning technologies. **Mollahosseini et al. (2017)** leveraged deep convolutional neural networks (CNNs) with datasets such as FER-2013 and AffectNet, achieving around 58% accuracy on FER-2013. While their approach benefited from diverse data and strong feature extraction, it demanded significant computational power and extensive labeled datasets. Conversely, **Arriaga et al. (2017)** introduced the Mini-Xception model—a lightweight architecture intended for real-time tasks. Though it achieved approximately 66% accuracy on FER-2013, its simplified design traded off robustness and performance in noisy or occluded conditions.

To mitigate dataset imbalance, **Zhang et al. (2018)** applied GAN-based data augmentation to FER-2013, improving model generalization and achieving roughly 71% accuracy. However, GANs occasionally introduced artifacts and posed stability challenges during training. In a different line of research, **Goodfellow et al. (2013)** proposed Maxout networks, which enhanced feature learning and reached about 85% accuracy on the MultiPie dataset—though this method wasn't evaluated on FER-2013 and had a more complex training procedure.

Temporal aspects of emotions were explored by **Dey et al. (2021)**, who combined CNNs with LSTM units to capture time-varying facial expressions from video sequences. They attained around 73.5% accuracy on the AFEW dataset, but the approach proved too resource-intensive for real-time deployment. For more efficient deployment, **Li et al. (2020)** adopted MobileNetV2 on FER-2013, reporting a 67.8% accuracy. Their model was highly compatible with mobile and edge hardware, albeit at a slight cost to accuracy compared to deeper networks.

Multimodal systems have also been investigated. **Tzirakis et al. (2017)** used a hybrid CNN-RNN model combining visual and auditory signals on the RECOLA dataset, achieving a correlation coefficient of ~0.75 for emotional dimensions. While this setup improved robustness, it required well-aligned multi-stream inputs, making it less ideal for real-time single-modality tasks.

FER techniques have been tested in specialized fields such as physiotherapy and athletic monitoring. **Kumar et al. (2022)** utilized CNN-GRU architectures for emotion classification in therapeutic settings, achieving 85% accuracy on FER-2013 and slightly less on a private rehabilitation dataset. However, generalization was limited due to the use of domain-specific and non-standardized data. **Zhang et al. (2021)** applied FER to monitor stress in athletes using a hybrid CNN trained on datasets like CK+, FER+, and sports-specific images, achieving about 82% accuracy. Despite promising results, the system showed vulnerability to motion blur and inconsistent lighting. Similarly, **Feng et al. (2017)** used a combination of geometric features and CNNs in rehab scenarios, reporting ~78.5% accuracy. Their system supported real-time feedback but underperformed in ethnically diverse samples and poorly lit environments.

These diverse studies underscore the balancing act between accuracy, computational demand, and real-time readiness. Deep and complex models often yield higher precision but lack feasibility for embedded applications, while compact architectures suit edge computing yet may compromise on accuracy. Notably, there remains limited exploration of FER in domains like sports and physiotherapy, where dynamic settings introduce challenges such as motion artifacts, varying illumination, and the necessity for contextual emotion understanding.

Author & Year	Dataset Used	Method / Model	Accuracy (%)	Strengths	Limitations
Mollahosseini et al. (2017)	AffectNet, FER-2013	Deep CNN	~58.0 (FER-2013)	High-capacity CNN; diverse training data	High computational cost; needs large labeled datasets
Arriaga et al. (2017)	FER-2013	Mini-Xception (light CNN)	~66.0	Real-time capable; fewer parameters	Lower accuracy; less robust to noise/occlusion
Zhang et al. (2018)	FER-2013	CNN + GAN augmentation	~71.0	Improves generalization; handles class imbalance	GAN artifacts; training instability
Goodfellow et al. (2013)	MultiPie	Maxout Networks	~85.0 (MultiPie)	Better feature representation; robust activation	Not trained on FER-2013; complex to train
Dey et al. (2021)	AFEW, CK+	CNN + LSTM	~73.5 (AFEW)	Captures temporal dynamics in videos	High memory and compute cost; latency
Li et al. (2020)	FER-2013	MobileNetV2 (lightweight)	~67.8	Edge-device compatible; fast inference	Lower accuracy than large models
Tzirakis et al. (2017)	RECOLA	CNN + RNN (multimodal)	~75 (corr. coeff.)	Uses audio + video inputs; multimodal learning	Needs synchronized data; limited deployment feasibility

Kumar et al. (2022)	FER-2013, custom physio	CNN + GRU	~85.0 (FER-2013)	Applicable to therapy contexts	Dataset not publicly available; domain-specific bias
Zhang et al. (2021)	CK+, FER+, custom sports	Hybrid CNN	~82.0	Sports performance monitoring	Sensitive to motion blur; varied lighting in field scenarios
Feng et al. (2017)	CK+, rehab dataset	Geometric features + CNN	~78.5	Real-time rehab feedback	Ethnic bias; poor lighting generalization

3. Methodology

3.1 Dataset and Preprocessing

This study utilized the publicly available **FER-2013 dataset**, which consists of **35,887 grayscale facial images**, each with a resolution of **48×48 pixels**. These images are labeled across seven emotional categories: *Angry, Disgust, Fear, Happy, Sad, Surprise,* and *Neutral*. Each image is encoded as a string of space-separated pixel values.

The preprocessing pipeline included the following steps:

- Images were converted into Numpy arrays and reshaped to a format of **48×48×1** to match the input requirement of the CNN.
- Pixel values were scaled to a **[0, 1] range** to enhance training speed and stability.
- Class labels were transformed using label encoding followed by **one-hot encoding** to support multi-class classification.
- The dataset was split into **80% training and 20% testing**, with **stratified sampling** to maintain class balance. Additionally, **10% of the training set** was reserved for validation purposes.

3.2 Model Architecture

The designed CNN model is tailored to process **48×48 grayscale images** and is composed of the following layers:

- **First Convolutional Block**: 32 filters with a 3×3 kernel, followed by **2×2 max pooling** and **25% dropout** for regularization.
- **Second Convolutional Block**: 64 filters of size 3×3, again followed by max pooling and dropout.
- The output from the convolutional blocks is **flattened** and passed into a **dense (fully connected) layer** with **128 ReLU units** and a **50% dropout rate**.
- A **softmax layer** is used for final classification across the seven emotion categories.

The model was compiled using the **Adam optimizer** with **categorical cross-entropy** as the loss function and was trained over **500 epochs** with a **batch size of 64**.

The architecture (in fig. 1) is deliberately lightweight and generalizable, making it appropriate for **real-time deployment** on **mobile and embedded systems**.

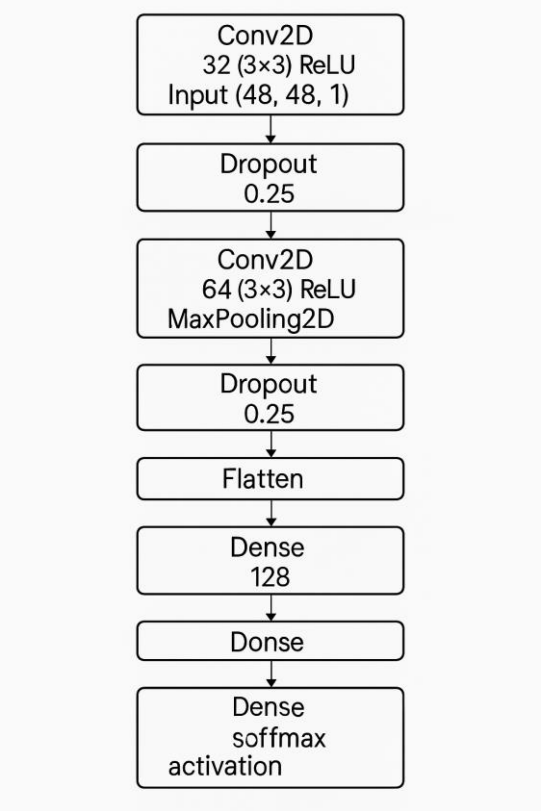

Figure 1: Model Architecture

This architecture prioritizes computational efficiency and generalization, making it deployable on mobile and edge devices.

3.3 Training Protocol

Training was conducted using the **Adam optimizer** in conjunction with **categorical cross-entropy** loss. The training process spanned **1,120 epochs**, using a batch size of **64**. To avoid overfitting, **early stopping** and **model checkpoints** were employed. Model accuracy was monitored as the primary metric to evaluate learning progression.

4.1 Performance Metrics

The trained model reached a **test accuracy of 92.39% (fig. 2)**, outperforming several well-established models trained on the same dataset.

Notable observations include:

- High recognition rates were observed for visually distinct emotions like **Happy**, **Angry**, and **Neutral**.
- Emotions such as **Fear** and **Surprise** were more challenging to differentiate, likely due to overlapping facial features in grayscale images.

Classification Report:

	precision	recall	f1-score	support
0	0.78	0.78	0.78	9
1	1.00	0.92	0.96	12
2	0.67	0.80	0.73	5
3	1.00	1.00	1.00	14
4	0.75	0.60	0.67	5
5	1.00	0.81	0.90	16
6	0.93	0.98	0.96	119
7	1.00	0.25	0.40	4
accuracy			0.92	184
macro avg	0.89	0.77	0.80	184
weighted avg	0.93	0.92	0.92	184

Figure 2: Classification Report

4.2 Confusion Matrix Analysis

The confusion matrix (in fig. 3) analysis highlighted the following:

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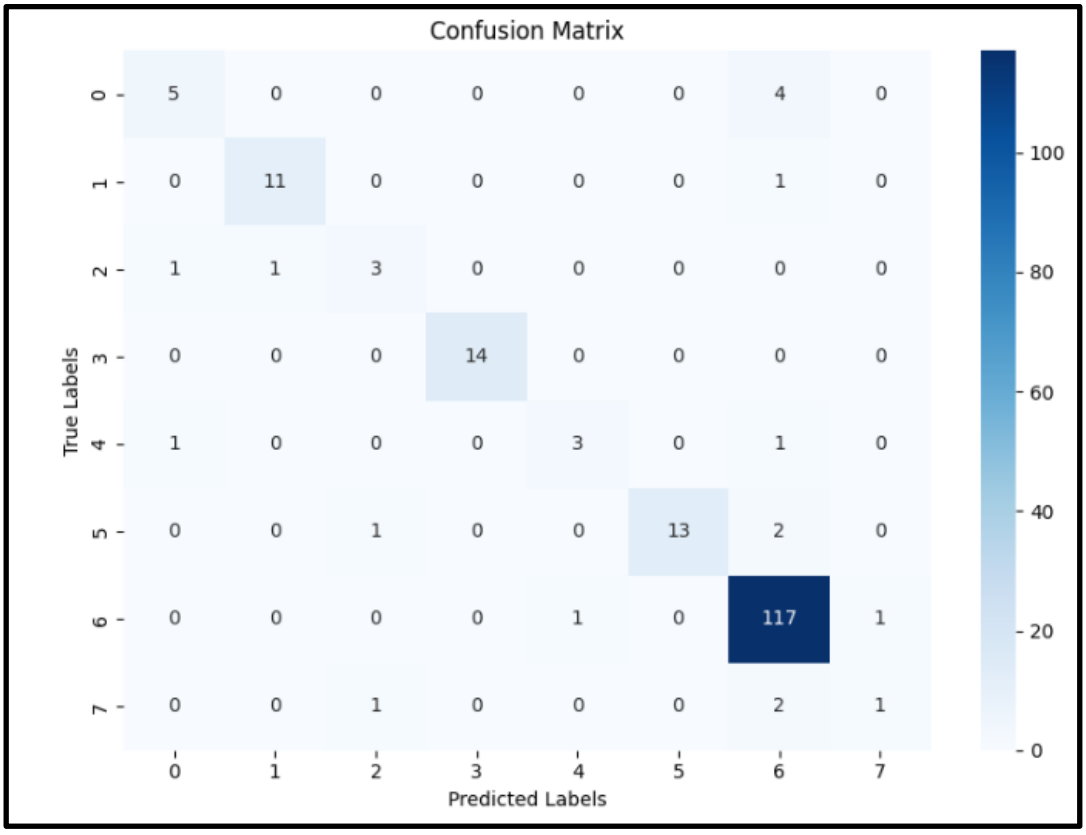

Figure 3: Confusion Matrix

- **Happy** and **Neutral** emotions were recognized with high precision, reflecting strong classification ability for these categories.
- There was some degree of **misclassification between Fear and Surprise**, which is consistent with observations in related studies, likely due to their overlapping facial features in grayscale imagery.
- The model maintained **low false positive rates across most emotion classes**, indicating a high level of discrimination and overall reliability.

5. Discussion

A comparative evaluation between FaceTrack and prominent models from previous literature underscores its effectiveness:

Author	Dataset	Model	Accuracy (%)	Remarks
Mollahosseini et al.	FER-2013	Deep CNN	~58.0	High accuracy potential but resource-heavy

Arriaga et al.	FER-2013	Mini-Xception	~66.0	Efficient, though less accurate
Zhang et al.	FER-2013	CNN + GAN Augmentation	~71.0	Better generalization, but adds complexity
Li et al.	FER-2013	MobileNetV2	~67.8	Suitable for edge devices, moderate result
Proposed (FaceTrack)	FER-2013	Lightweight CNN	**92.39**	High accuracy, low complexity

FaceTrack stands out by offering a high-accuracy solution while avoiding the complexity of hybrid, GAN-augmented, or multimodal architectures. Its balance of **performance and simplicity** makes it highly viable for deployment on portable devices in real-world scenarios.

6. Conclusion

This research presents **FaceTrack**, a convolutional neural network designed specifically for recognizing facial emotions related to stress in athletic and therapeutic contexts. Achieving **92.39% test accuracy** on the FER-2013 dataset, the model performs competitively with significantly reduced computational overhead—making it practical for **real-time use on mobile and edge devices**.

The utility of FaceTrack spans a wide range of domains including **sports training**, **psychological stress assessment**, and **physiotherapy**. By offering fast, objective feedback, it paves the way for **emotionally responsive health and performance monitoring systems**.

Looking forward, enhancements will aim to:

- Improve resilience against **occlusions** and **lighting inconsistencies**
- Enhance the detection of **subtle or compound emotions**
- Extend the model to **temporal sequences**, enabling video-based analysis of emotional dynamics

By making the source code and model freely available on **GitHub** and **Kaggle**, this work also encourages collaboration and further innovation in the field of **emotion-aware computing**.

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A Study on Mental Well-being of Intraday Option Traders with Reference to Navi Mumbai City

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Abstract

The world of intraday option trading is characterized by high volatility, rapid decision-making, and significant financial risk—all of which can have a profound impact on an individual's mental well-being. This study aims to explore the psychological and emotional challenges faced by intraday option traders operating within Navi Mumbai city. Using a mixed-method approach, the research combines quantitative surveys and qualitative interviews to assess stress levels, anxiety, sleep patterns, and coping mechanisms among traders. Key variables such as trading frequency, capital exposure, market experience, and lifestyle factors are also examined. The findings reveal a strong correlation between intraday trading intensity and heightened psychological stress, with many participants reporting symptoms of anxiety and burnout. The study also points out ways to stay strong and support systems that can help reduce these effects. The research highlights the urgent need for mental health awareness and preventive interventions tailored to this high-pressure profession. It offers practical recommendations for traders, financial institutions, and policymakers to foster a healthier trading environment in the region.

Key words

Intraday option traders,Intraday trading psychology ,Option trading mental health , Intraday trading stress , Trader emotional well-being

Introduction :

Global studies indicate a high prevalence of stress and anxiety among day traders.. A cross-sectional study in Saudi Arabia found that around 22% of traders experienced moderate to extremely severe stress, with financial pressure and emotional instability playing major roles Similar research It emphasizes that the addictive and leveraged nature of options trading intensifies psychological strain, contributing to gambling-like behavior, compulsive tendencies, and emotional instability. In India, traders often feel mentally tired, anxious, and

depressed because of the ups and downs in the market, long hours in front of screens, and high pressure to perform well. Reddit discussions reveal that stress may manifest through physical symptoms—such as fatigue, insomnia, and heart palpitations—particularly following losses or during periods of heightened market pressure. Intraday traders frequently report emotional challenges like fear of loss, greed, and overconfidence—states notoriously difficult to master in fast-moving markets.While global and Indian studies show similar patterns, little research focuses on intraday options trading specifically in Navi Mumbai. This locale brings unique pressures—from a growing derivatives market to the city's fast-paced culture. By zeroing in on this region, the study aims to Provide empirical insights tailored to local conditions, trader demographics, and support frameworks.Fill a gap in literature where most research emphasises equity traders or international contexts. Support the development of targeted interventions—mental health workshops, regulatory insight, and corporate wellness programs relevant to Navi Mumbai

Review of Literature

Collard (2009) found that investors—especially women—prefer minimizing risk over maximizing returns, even for long-term investments like pensions. This means they often make choices that might not give them the best retirement income.

Ciccone (2003) found that companies hyped by analysts tend to underperform. Overly high expectations often aren't met, so stock prices fall and returns suffer.

(Shefrin & Statman, 1985): Investors frequently sell winners too quickly (to lock in gains) and hold losers too long (to avoid regret).

Seru et al. (2010) and Odean (1998) show that investors with disposition bias earn lower returns. Overconfident traders often trade too much, ignoring costs and hurting their performance (Odean, 1999; Trinugroho, 2011).

Chandra (2008) confirmed that various psychological and emotional biases—like representativeness, overconfidence, anchoring, regret aversion, mental accounting, cognitive dissonance, greed, and fear—strongly influence how investors perceive risk and make decisions.

Tehran (Masomi & Ghayekhloo, 2011): Institutional investors also display heuristics and biases, with anchoring and gambler's fallacy being most common.

OBJECTIVES OF THE STUDY

1. To assess the levels of mental stress and emotional well-being among intraday option traders in Navi Mumbai.
2. To identify key factors contributing to psychological pressure in intraday trading (e.g., market volatility, financial risk, screen time, etc.).
3. To explore coping mechanisms and support systems used by traders to manage stress.

4. To suggest strategies for improving mental well-being and work-life balance for intraday option traders.

METHODOLOGY

Research Methodology

This study uses a **descriptive research design**, focusing on describing specific variables. It requires a good level of scientific understanding from the researcher. The necessary information has been collected using both **primary and secondary data** sources.

Sample Design:

- **Sampling Method:** A **random sampling method** was used to select participants.
- **Sample Size:** The study was conducted with a sample of **100 respondents**.
- **Data Collection Tool:** Data was collected using a **structured questionnaire**.
- **Research Design:** The project is based on both **exploratory** and **descriptive** research approaches.
- **Sampling Unit:** The sampling units are **intraday traders** who responded to the survey.

DATA COLLECTION

Age of Respondents	%
Below 25	35
25–35	21
36–45	16
46–55	17
Above 55	11
Total	100

Gender	%
Male	69
Female	31
Total	100

Education Qualification:	%
12th Pass	14
Graduate	68
Postgraduate	18

Total	100

How long have you been trading options intraday?	%
Less than 1 year	32
1–3 years	26
3–5 years	24
More than 5 years	18
Total	100

Average daily trading capital:	%
Less than ₹10,000	45
₹10,000 – ₹50,000	28
₹50,000 – ₹1,00,000	22
Above ₹1,00,000	5
Total	100

How many hours a day do you spend trading or monitoring the market?	%
Less than 2 hours	47
2–4 hours	24
4–6 hours	11
More than 6 hours	18
Total	100

On average, how often do you experience a trading loss?	%
Daily	28
2–3 times a week	28
Weekly	25
Rarely	19
Total	100

Do you use any of the following for trading decisions? (Select all that apply)	%
Technical analysis	62
News-based analysis	24
Social media/Forums	3
Tips from others	8
Own strategy	3
Total	100

Do you feel financially insecure due to inconsistent trading results.	%
Strongly agree	56
agree	25
Neutral	10
Disagree	6
strongly disagree	3
Total	100

Do you feel your sleep is affected due to thoughts about trading.	%
Strongly agree	29
agree	36
Neutral	21
Disagree	10
strongly disagree	4
Total	100

How do you usually deal with stress after a bad trading day?	%
Take a break	36
Talk to friends/family	23
Meditation/Exercise	30

Continue trading to recover losses	11
Total	100

Do you think mental health support should be made available specifically for traders?	%
Strongly Agree	32
Agree	29
Neutral	26
Disagree	6
Strongly Disagree	7
Total	100

FINDINGS

1.This skew towards a younger demographic suggests that intraday option trading is more attractive to the youth, possibly due to the appeal of quick profits, digital trading platforms, and a higher risk appetite.

2.This indicates that intraday option trading is currently **male-dominated**, although a notable **female participation of 31%** reflects growing involvement of women in this high-stakes financial activity.

3.The findings suggest that **86% of traders** possess at least a graduate-level education, indicating a strong academic foundation among participants.

4.The findings indicate that a significant proportion of traders (58%) are relatively new to intraday option trading, with less than three years of experience. This suggests that the market is attracting a growing number of newcomers, many of whom may be exposed to the psychological pressures of trading without extensive experience or coping mechanisms.

5.The findings suggest that a majority of intraday option traders operate with relatively modest capital, with **73% trading below ₹50,000 per day**. This indicates a predominance of retail traders who may be more susceptible to emotional and financial stress due to limited capital buffers.

6.Nearly half of the traders (47%) were involved in trading or market observation for less than two hours daily, suggesting that many engage in trading part-time or alongside other responsibilities.

7.The data indicates that a majority of traders (81%) encounter losses at least once a week, with over half (56%) experiencing them **multiple times per week**. This frequent exposure to financial setbacks may contribute significantly to stress, anxiety, and reduced mental well-being.

8.The findings show that **technical analysis is the most widely used tool**, employed by nearly two-thirds of the respondents. A smaller segment (24%) bases decisions on current news and market events, while very few depend on social media, personal strategies, or external tips.

9.The findings reveal that a substantial majority—**81% of traders**—acknowledged feeling financially insecure to some degree due to inconsistent trading results. This indicates that the volatility and unpredictability of intraday option trading can significantly impact traders' sense of financial stability.

10.The findings indicate that a significant portion of traders (**65%**) experience sleep disturbances related to trading concerns. This suggests that the psychological impact of intraday trading often extends beyond market hours, potentially affecting rest and overall mental health.

11.The findings highlight that the majority of traders adopt positive coping strategies such as taking breaks and practicing meditation or exercise to manage stress.

12.The findings indicate that a majority of traders (**61%**) recognize the importance of providing dedicated mental health support tailored to the unique challenges faced by traders.

RECOMMENDATIONS

1. Given the predominance of younger traders in intraday option trading, educational programs should be developed to build financial literacy, risk awareness, and emotional resilience among youth, helping them manage the unique pressures of high-risk trading.

2. Efforts should be made to support and encourage greater female participation in intraday trading through awareness campaigns and gender-sensitive mental health resources, fostering a more balanced and inclusive trading community.

3.Since most traders are well-educated, mental health interventions can incorporate advanced knowledge-based strategies, such as cognitive-behavioral approaches, to help traders better cope with the psychological challenges of trading.

4. Special attention should be given to traders with less than three years of experience by providing mentoring, stress management training, and access to psychological support to reduce the risk of mental health issues due to inexperience.

5.Considering that many traders operate with limited capital, financial counseling and risk management workshops should be introduced to help traders develop better money management practices and reduce emotional stress linked to financial insecurity.

6.Encourage traders to maintain a balanced trading schedule, especially those trading part-time, by emphasizing the importance of breaks and managing trading hours to prevent burnout and cognitive fatigue.

7.Traders should be trained to psychologically prepare for frequent losses, incorporating techniques like emotional regulation and loss acceptance to minimize stress and anxiety related to trading setbacks.

8. Since technical analysis is the predominant tool, continuous training in technical and fundamental analysis should be provided, along with fostering critical thinking to reduce over-reliance on external tips or social media influences.

9.Programs focused on building financial resilience and planning should be offered to help traders cope with the unpredictability of trading outcomes and reduce feelings of financial insecurity.

10.Workshops on stress reduction, sleep hygiene, and relaxation techniques should be made available to help traders manage sleep disturbances caused by trading-related anxiety.

11.Promote healthy coping strategies such as taking breaks, meditation, and physical exercise among traders, while discouraging risky behaviors like impulsive trading to recover losses.

12.Given the recognition among traders for tailored mental health support, specialized counseling services, peer support groups, and helplines should be established to address the specific psychological challenges faced by intraday option traders

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Deployment of Artificial Intelligence for training and progress of manpower

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Abstract

In the rapidly evolving sector of higher learning, specialists are constantly searching for innovative approaches to enhance instructional accomplishments and meet the shifting needs of individuals. Machine intelligence has significantly changed the way that educational programs are implemented, approached, and optimized. It explores the profound impact artificial intelligence has on learning and development, giving experts a greater grasp of how to use the program to create more effective and personalized learning environments. Although algorithmic learning has historically dominated media attention, it is also going through a golden period in practical applications right now. Google introduced Bard, a rival smart chatbot, while Microsoft founder Bill Gates referred to ChatGPT as the most significant technological advancement in millennia. The extent of the impact that increasing artificial intelligence (AI) innovation will have been hard to predict. However, the globe has benefited much from its technological innovations, which have increased medical care, expanded educational options, and increased worker productivity. Even with its advancements, artificial intelligence remains a controversial topic. It primarily addresses the idea of Artificial Intelligence. How AI is used in training and progress of manpower in an organization.

Keywords: Artificial Intelligence, Robotics, NLP, Computer Vision and Machine Learning.

1.0 Introduction

A subfield of information technology is artificial intelligence. It entails creating computer programmed to carry out operations that usually need cognition from humans. Artificial intelligence algorithms are capable of acquiring knowledge, perceiving, figuring out solutions, comprehending language, and possibly applying mathematics. AI is employed in a variety of fields nowadays, ranging from autonomous cars to personal digital assistants. AI is a field that is rapidly evolving. Even while AI is sometimes portrayed in scientific works as robots that can be described as similar to humans as viable.[1]

Nonetheless, the field of robotics is engineering that works with automated machinery. Robotics are programmed machines that can typically perform a range of tasks fully or partially on their own. Three primary components are necessary to make up a robotic device: (a) Robotics use sensors as well as actuators to

communicate alongside the outside environment. (b) Robotics can be programmed. (c) Most robots can be fully or partially automated.[2] The reason why robotics are typically autonomously is that certain aren't. For instance, telerobots are fully operated by an individual administrator, although telerobotics remains to be a subfield of robotics. Robotic with artificial intelligence will ultimately act as the link amongst robotics as well as AI. These are actually robotics that artificial intelligence programmed operate.[3]

2.0 Domains within AI

The large area of AI contains a number of smaller categories, each of which has a distinct focus along with a variety of methods. Among the many popular branches in AI are depicted in the figure 1 given below:

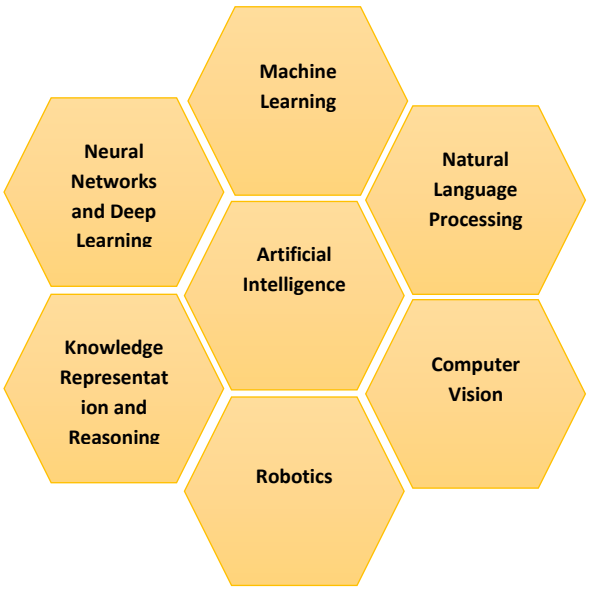

Fig 1: Domains of Artificial Intelligence[4]

2.1 Machine Learning: The category of AI that concentrates on giving algorithms the ability to acquire knowledge from facts and progressively improve their skills in regardless of the requirement for specific software.[5]

2.2 Natural Language Processing: The category of AI which works on presenting machines the capacity to grasp, translate, as well as produce words that humans use.[6]

2.3 Computer Vision: A category of AI which works on providing computers the capacity to recognize as well as interpret visual data, including pictures and videos.[7]

2.4 Robotics: A category of AI concentrating on creating physical machines, such as automated machines, that are capable of carrying out duties and acting in the actual environment.[8]

2.5 Knowledge Representation and Reasoning: A category of AI which specializes on how expertise and content are represented and altered in machines, as well as how those machines can think and arrive at judgements using that data.[9]

2.6 Neural Networks and Deep Learning: A category of AI that specializes in processing and analysing vast volumes of complicated data using artificial neural networks, which are a kind of mathematical methodology, like in the instances of speech along with recognizing images.[10]

3.0 Categories of AI

There are various classifications for AI. In regard to effectiveness, AI can be divided into three distinct categories. However, according to the number of parts, they are three different kinds of AI, which are depicted in the figure 2 given below:

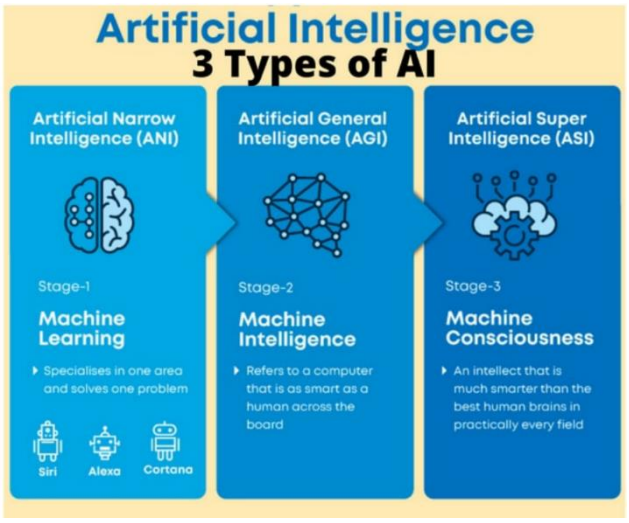

Fig 2: Categories of Artificial Intelligence[11]

3.1 Artificial Narrow AI: At present, artificial narrow intelligence, sometimes known as weak AI or narrow AI for short is the only type of AI in practice. Every other kind of AI is only hypothetical. It might be programmed to do a circumstantial, definitive activity far more quickly as well as precisely than the individual brain is competent of. It is unable, nevertheless, function beyond of its assigned role. Relatively, it concentrates on a particular portion of cognitive amplitude as well as progresses along that scope. It includes Siri, which is Watson by IBM, as well as Alexa from Amazon.[12]

3.2. General AI: The term strong AI, or general AI, is merely an intellectual idea at this essence. Without necessitating individual training of the core models, AGI can use its current expertise and abilities to do new

tasks in a completely different environment. This feature enables AGI to learn and execute any mental task that a human can.[13]

3.3. Super AI: It is similitude to AGI (acronym “artificial general intelligence”) as well as super AI is also merely conceptual. It is often called “artificial superintelligence”. If Super AI were ever developed, it might be able to rational, recognize, acquire knowledge, make determination, as well as be analytical dominant to humans. Uses with Super AI abilities are expected to have improved past the platform of appreciating human feelings and events to a place where they can sense emotions, wants, and hold distinct views as well as ambitions.[14]

4.0 AI Models

A application which examines statistics within search of trends and projections is known as an artificially intelligent (AI) framework. The process of developing and implementing a model using artificial intelligence is known as AI engineering. The simulation of AI is strongest once it obtains several data sources and mimics the thinking of people. A machine learning strategy applied within a company can effectively resolve complicated problems at an affordable price of administration. Every artificial intelligence algorithm has a distinct function and operates in a unique way. Since every mathematical pattern are also generated by AI, is a convergence. Templates can be combined by customers to accomplish a desired purpose.[15]

The definition of "machine learning," which was first used in the year of Nineteen Fifty Nine by US computer researcher Arthur Samuel, is "a device's capability to acquire knowledge without getting specifically programmed." At the simplest manner, by obtaining input data, algorithmic learning analyzes and determines results within a tolerable range using predetermined algorithms. These procedures gain "intelligence" as time passes as a consequence of gaining knowledge and improving how they work in response to fresh information. Four categories of machine learning techniques are available as depicted in figure below:[16]

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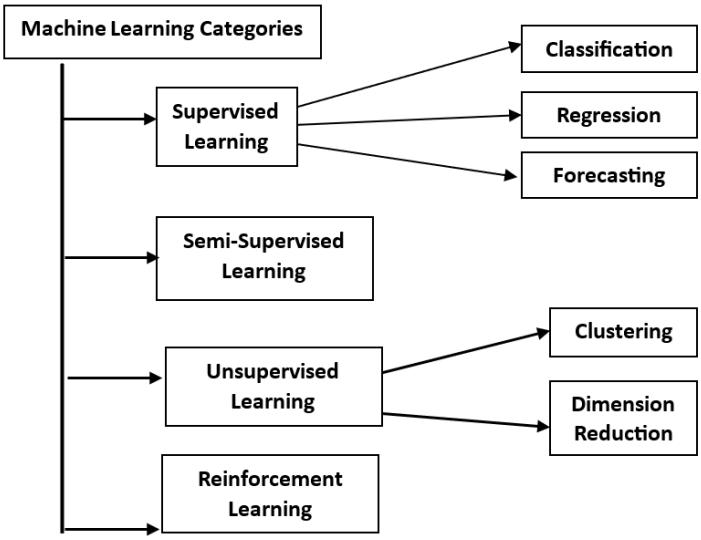

Fig 3: Categories of Machine Learning[16]

4.1 Supervised learning: Machines learn by demonstration when they are under supervision. A data source collection containing intended inputs as well as outcomes is supplied by the consumer to the method of machine learning, that must then determine how to obtain those inputs as well as the outcomes. Though its developer is conscious of the proper remedies to the issues, the process identifies patterns in the data, learns from results, and produces projections. Predictions generated by the model are corrected by the user after attaining a high level of effectiveness or dependability.[17] The items that follow fall under the heading of guided advancement:

4.1.1 Classification: The aim of applying machine learning effort in activities such as categorization is to determine which category fresh data points belong to and to deduce a response from data seen. As an example, a machine must take into account recent empirical data while determining if a message is "spam" or "no junk" and classify it accordingly.

4.1.2 Regression: Determining and comprehending the relationships between variables is the task of an automated learning effort in issues related to regression. Because regress assessment focuses on only one reliant factor & several separate variable modifications, it is particularly useful for forecasting and preparation.

4.1.3 Forecasting: It is the technique of estimating future events from data collected in the recent past as well as current. It is frequently used to analyze patterns.

4.2 Semi-supervised learning: It employs pair of labeled & unlabelled information, it is similar to supervisory learned. The main component of data with labels is the particulars, that must incorporate pertinent identifiers for the method to comprehend what it contains. These descriptions do not exist in unlabeled information. Machine learning techniques are able to label unlabeled data through using this mixture.[18]

4.3 Unsupervised learning: In this instance, an automatic learning process searches the data for patterns. There isn't a remedy key or a single operator to provide direction. Instead, the machine looks for linkages and correlations by analyzing the data that is already there. In an unsupervised education cycle, an algorithm for machine learning continues to evaluate and react to vast volumes of data. The approach aims to organize the data in order to describe its organization. Clusters the information or displaying it in an additional visually appealing way may be necessary to achieve this. Its capacity to draw conclusions from data steadily gets enhanced and further refined as it evaluates further information.[19] The following fall under the umbrella of unsupervised training:

4.3.1 Clustering: It refers to the procedure for assembling sets of linked data (based on predetermined criteria). It's useful for segmenting knowledge into numerous categories and conducting independent analyses of every category to search for patterns.

4.3.2 Dimension reduction: It involves cutting down on the amount of variables considered when trying to get the exact data required.

4.4 Reinforcement learning: It is centered on structured learning procedures in which an algorithm used in machine learning gets an assortment of inputs, outputs, as well as variables. Once the parameters have been established, the machine learning system keeps track of and evaluates each result to determine which is best before trying to look into other options. Reinforcement instruction is a method of teaching machinery by doing. By learning from past experiences, it begins to adjust its approach in response to the situation in order to achieve the best result.[20]

5.0 Machine Learning Algorithms

There exists different AI models to solve problems from different domains, which include Decision Tree, DNN (acronym “Deep Neural Networks”), Linear Regression, Logistic Regression, LVQ (acronym “Learning Vector Quantization”), Random Forest, KNN (acronym “K-Nearest Neighbors”), LDA (acronym “Linear

Discriminant Analysis"), SVM (acronym "Support Vector Machines") and Naive Bayes.[21] Below are some of the popular models listed with their fundamentals implementation procedures:

5.1 Deep Neural Networks (DNN): Machine learning has an element called DNN. Having many channels for data parameters to flow via deep neural networks (D mimics the structure of the nervous system in humans.[22] The following are the procedures to be followed in order to execute the algorithm:

1. Arrange the parts and framework.
2. Establish baseline bias as well as weighting.
3. Utilize the supplied data to derive projections.
4. Calculate the expected error.
5. Determine variations and make factor updates.
6. Use refinement to fine-tune biases along with levels.
7. Repeat the learning procedure.
8. Evaluate the design's functionality.
9. Continue to refine the framework.
10. Apply the learned paradigm to practical situations.

5.2 Support Vector Machines (SVM): An established machine learning algorithm employing little research but correctly classifies content.[23] The following are the procedures to be followed in order to execute the algorithm:

1. Perform data preprocessing (such as scaling).
2. Select the appropriate values (C, gamma for non-linear kernels) and kernel.
3. Use the experimental information to learn the SVM model.
4. Assess the framework using pertinent metrics (such as precision, efficacy, and recollection) along with experiment information.
5. Adjust settings using methods like crossover validation as necessary.

5.3 Naive Bayes: Machine learning technique presumes each value of the source information are interrelated.[24] The following are the procedures to be followed in order to execute the algorithm:

1. Preparing a dataset.
2. Applying Naive Bayes on its Learning to operate Set.
3. Forecasting the Trial Outcome.
4. Presenting the examination set outcome; (Puzzle matrix generation).

5. Evaluate correctness of the outcome.

6.0 AI Transformation

Our approach to learning is changing because to AI. As well as by the description, the method of instruction we use expedites your process and the team members' professional growth. Therefore human intellect is perpetually superior, regardless of how sophisticated AI becomes. The following are some major advantages of utilizing AI to speed up depth learning and enhance your learning procedures:[25]

6.1 AI aids the learner, the staff: It provides an additional customized learning atmosphere. By facilitating content through widely available instructional technology, you may expedite the transmission of knowledge. Additionally, this helps strengthen learning objectives. Tailor video material to establish a more intimate individually relationship.[26]

6.2 AI aids the L&D manager: It accelerates the instruction and raise the percentage of those who finish. It offers customized assessment strategies, doing away with the requirement for conventional review approaches. It streamlines the procedure of learning as well as making instructional resources available globally by translating it to numerous languages. It takes up virtual tutoring to save up hours spent creating materials. AI is also capable of filling in the role of 24/7 digital tutor. Workers can ask inquiries and receive prompt answers from a chatbot powered by AI, which has access to all instructional content. They can also halt and restart learning at any time.[27]

7.0 Use-case of AI in staff Training & Progress

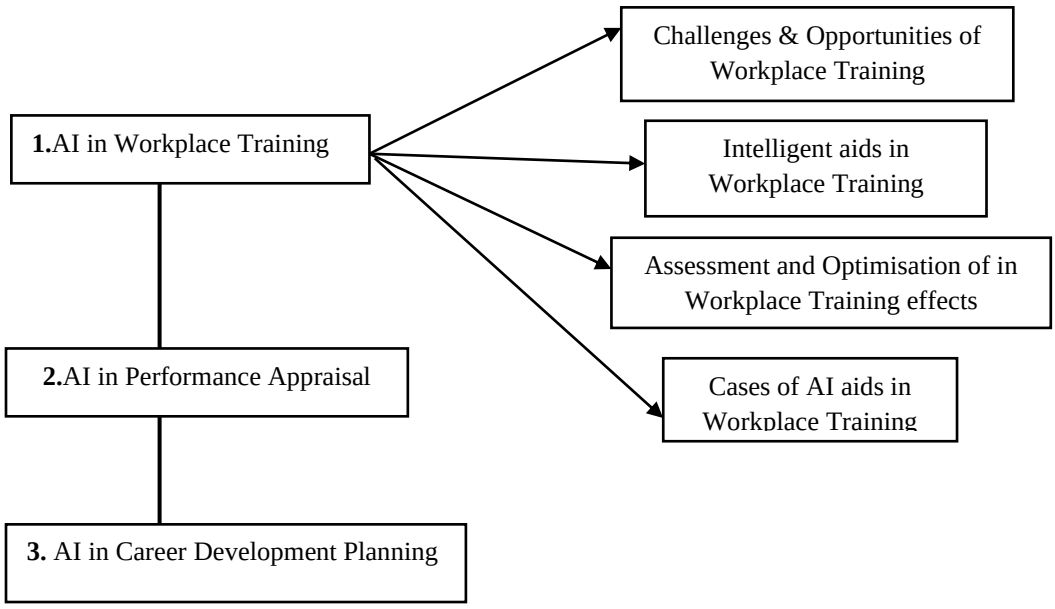

Fig 4: Flow-chart of AI Use Case[28]

7.1 Utilization of AI for workplace training

Employers can give their staff members possibility overall growth learning through classroom instruction, and as advances in artificial intelligence (AI), it will become practical to use AI in this capacity. The deployment of artificial intelligence within profession environment instruction will be examined in the following paragraphs.[29]

7.1.1 Possibilities as well as obstacles associated with job guidance: Employee education has a number of difficulties in today's environment. Initially, workers frequently deal across a plethora of data pieces due to this data detonation, which makes it challenging to sort through and assimilate helpful data. Initially, workers frequently deal with a plethora of data pieces due to this data bursting, which makes it challenging to sort through and assimilate helpful data. Furthermore, certain businesses encounter issues like exorbitant costs for instruction and challenges in assessing the results. Nonetheless, inventive possibilities for problem-solving are opened up by the use artificial intelligence software.[30]

7.1.2 Clever tools for job Orientation: Initially, artificial intelligence may suggest instruction along with additional educational amenities that suit the preferences of staff members according to existing educational histories, professional growth aspirations, in addition further comprehension, using customized suggestion techniques. a combination of machine learning and machine translation technologies, the computerized instructional assistance software may converse intellectually among staff members to react for inquiries plus offer suggestions.[31]

7.1.3 Evaluation and optimization of the benefits of vocational education: Additionally, instructional impacts are able to optimized as well as evaluated with the help of machine learning technologies. The academic results and rewards that job-related instruction are able to objectively evaluated using student conduct evaluation and information extraction technologies.[32]

7.1.4 Instances Where AI Helps with Professional Education: Certain companies are currently utilizing AI technologies in job orientations as of right now. To supply staff with individualized instructional resources and education pathways according to their studying preferences and past performance, some businesses, for instance, use smart instructional technology.[33]

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7.2 Utilizing Machine Learning in Assessment of Achievement: Administration of human resources includes assessments of achievement as a key component. Organizations are able to comprehend their staff's abilities and contributions by assessing and giving suggestions for improving their achievements. This allows them to offer possibilities for advancement and fair compensation benefits. Gathering and analysing data. By merging task information achievements, and other pertinent data about staff, AI may computerize the gathering and processing of enormous amounts of material. AI may streamline conventional appraisal processes, reducing subjectivity and inaccuracy and increasing the examination's legitimacy as well as reliability. AI may also be used to forecast and analyse patterns in staff achievement using data mining as machine learning technologies. This helps businesses spot possible issues early on and take prompt action to address them.[34]

7.3 AI Role in Occupational Strategy: Initially, artificial intelligence may offer workers individualized guidance on professional advancement. Conventional professional advancement strategy frequently ignores the unique characteristics and untapped possibilities for future growth of every staff member, relying instead on the knowledge and discretion of human resources professionals and management. Conversely, artificial intelligence (AI) has the capacity to precisely evaluate and examine every worker by examining their individual data, productivity, and habits of conduct. It can then offer individuals tailored plans for professional advancement and guidance to ensure that their growth is at its best. growth.[35]

8.0 Advantages of AI

There are certainly many advantages to utilizing AI for staff advancement and instruction. Initially instruction and growth strategies can be tailored using driven by artificial intelligence technologies to each staff requirements, choices, and developmental choices. Increased loyalty, enhanced productivity at work, and enhanced learning may arise from it.[36]

8.1 Customized Educational Journeys: Designed information Distribution: artificial intelligence examines user characteristics, methods of instruction, and achievement statistics to provide knowledge that matches perfectly to each worker, making confident the instructional material meets each person's requirements.

8.2 Modular Education: Instantaneous Comments along with Improvements: Artificial intelligence (AI) systems monitor staff advancement as well as offer immediate suggestions. In order to keep professionals motivated to their best, the framework adjusts the challenging nature of the materials according to their achievements.

8.3 Increased Involvement: based on artificial intelligence systems frequently include enhanced components, experiments, including engaging sections with the goal to maintain staff members interested. It encourages involvement that is proactive, persistence in learning, plus an increase in enthusiasm.

8.4 Effective Article Production: Computerized Program Layout: Through the use artificial intelligence filmmakers, curriculum may be created via the help of tests, evaluations, and sometimes movies. The technique of creating material is streamlined, freeing up teaching professionals to concentrate on key elements.

8.5 Statistics for Forecasting: Finding Skills shortages: AI looks at data on staff productivity to find regions in need of enhancement and shortages of abilities. That facilitates anticipatory resolution of particular the employees demands by human resources and instructional management.

8.6 The Mindset of Constant acquiring knowledge: Prospects for Small-scale instruction: Artificial Intelligence enables the provision of short, personalized educational courses. That encourages an environment where knowledge never stops, enabling staff members to pick up fresh competencies on an individual schedule an interfering from regular tasks.

8.7 Time and Money Benefits: Computerized Management: AI manages and tracks program admissions, maintains records of staff advancement, and generates accounts, among other job duties. It saves both cash and period by lessening the workload for organizational and personnel managers.

8.8 NLP: NLP acronym “Natural Language Processing”. It facilitates user-friendly screens and chatbots that respond quickly to worker inquiries, thereby fostering a smooth process of education. Training is made easier by this equipment, which also offers controlled by speaking interactions.

Conclusion

This paper describes about the theory of Artificial Intelligence, their sub domains, categories of AI such as Artificial Narrow AI, General AI, Super AI and also AI models like Deep Neural Networks, Support Vector Machines etc. It also elaborates the use case of AI for the priming as well as progression of workers. Further, it elaborates the advantages of Artificial Intelligence for pedagogy and growth of employees.

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FinTech Adoption Among Youth: Evaluating Mobile Banking Experience of College Students in Urban Areas

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Abstract

In recent years, mobile banking has emerged as a cornerstone of FinTech innovation, revolutionizing the way individuals especially youth engage with financial institutions. This study explores the adoption patterns and user satisfaction of mobile banking services among college students in urban areas. As digital natives, students play a crucial role in shaping the future trajectory of FinTech-enabled banking systems.

The research focuses on evaluating mobile banking experiences across key dimensions: ease of use, security, trust, accessibility, and overall satisfaction. A structured survey conducted among college students in Mumbai indicates high usage of mobile banking for routine transactions such as fund transfers and bill payments. However, satisfaction levels are significantly influenced by app design, responsiveness, and perceived safety.

The study further uncovers challenges including digital fatigue, app clutter, and inconsistent customer support. Based on these insights, actionable recommendations are proposed for banks and FinTech developers to enhance mobile banking engagement among the youth.

This research contributes to the broader discourse on youth-centered financial innovation, emphasizing the importance of digital inclusion and user-centric design in the evolving FinTech landscape.

Keywords : FinTech, Mobile Banking, Youth, College Students

Introduction

The emergence of financial technology (FinTech) has revolutionized the banking sector in India, with mobile banking standing out as one of its most impactful innovations. Mobile banking provides a suite of services including fund transfers, bill payments, balance inquiries, and investment options conveniently accessible via

smartphones. With over **1.2 billion mobile subscribers** and robust digital infrastructure, India has witnessed a substantial surge in mobile banking adoption in recent years (TRAI, 2023).

Among the key drivers of this digital transformation are **college students**, who represent a mobile-first, tech-savvy generation. According to the **India FinTech Report (2023)**, users aged **18–25** contribute to nearly **30% of all mobile banking app downloads** in urban India. This demographic not only actively uses mobile banking for everyday transactions but also serves as early adopters influencing future trends in digital finance. Factors such as increased smartphone penetration, affordable internet access, and initiatives like **Digital India** have further accelerated FinTech engagement among youth.

However, despite the widespread usage of mobile banking, satisfaction levels among college students remain inconsistent. User satisfaction is significantly influenced by factors such as app usability, transaction speed, security features, and the quality of customer support. College students, in particular, expect seamless app experiences, minimal transaction failures, and efficient customer service. Nevertheless, recurring issues such as technical glitches, inadequate digital financial literacy, and privacy concerns continue to affect the overall user experience

This research aims to evaluate the mobile banking experience of college students in urban areas by examining their adoption patterns, satisfaction levels, and the challenges they face. By focusing on this dynamic and influential user group, the study seeks to contribute meaningful insights into youth-oriented FinTech adoption and offer recommendations to enhance mobile banking services tailored to their evolving expectations.

Literature Review

The evolution of mobile banking as a FinTech innovation has significantly influenced how users—particularly young, urban populations—interact with financial services. College students, being tech-savvy digital natives, are increasingly adopting mobile banking for its convenience, speed, and round-the-clock access. Several studies have explored various factors affecting FinTech adoption, including trust, usability, digital literacy, and customer satisfaction.

Gupta and Arora (2019) examined the factors influencing mobile banking adoption among Indian millennials and concluded that perceived ease of use, usefulness, and trust were significant predictors of adoption intent.

The study highlighted that younger users are more likely to adopt mobile banking when the app offers intuitive interfaces and secure transactions.

Kaur and Arora (2021) extended this by analyzing how the **usability of mobile banking applications** affects user satisfaction. Their research emphasized the role of interface design, responsiveness, and technical stability in driving continued usage among urban users, including students.

According to Sharma (2022), in a case study of urban college students in Maharashtra, while mobile banking is widely used for routine transactions such as fund transfers and recharges, many students reported dissatisfaction with slow customer service, transaction errors, and concerns over app data security. The study called for more youth-focused mobile banking solutions that align with the digital habits and expectations of students.

The **India FinTech Report (2023)** states that users aged 18–25 account for a growing share of mobile banking activity in India, but many still lack **digital financial literacy**, which limits their ability to engage with advanced features like budgeting tools, investment tracking, or loan applications.

Further, GSMA (2022) reported that although smartphone ownership among urban youth is high, **gender, socio-economic background, and regional disparities** still affect digital banking usage patterns. This underlines the importance of inclusive design and education when developing mobile banking apps for young users.

Despite the surge in mobile banking use, especially post-COVID-19, studies focusing specifically on **urban college students** remain limited. There is a research gap in understanding how students perceive their mobile banking experience, what drives their satisfaction, and what challenges they face in real-world usage. This study addresses this gap by evaluating FinTech adoption and mobile banking satisfaction among college students in urban India.

Problem Statement

Mobile banking has become increasingly popular among urban college students in India, who are tech-savvy and frequent users of FinTech services. Despite high adoption rates, their actual experiences—such as satisfaction levels, technical issues, customer support, and awareness of advanced features—remain

underexplored. Students often face challenges like app glitches, limited financial literacy, and concerns over data security. This study aims to evaluate their mobile banking experience, identify usage patterns and key issues, and provide insights to help banks and FinTech companies improve digital services tailored to the needs of young users.

Research Gap

While mobile banking is widely studied in the context of rural users and working professionals, limited research focuses on **urban college students**, despite their high digital engagement. Existing literature often overlooks key aspects like **user satisfaction, technical issues, customer support, and trust in security** from the perspective of youth. Additionally, there's a lack of insight into their **awareness and usage of value-added services**. This study addresses this gap by exploring the mobile banking experience of urban students, offering a focused understanding of their needs, behaviours, and expectations from FinTech platforms.

Research Objectives

1. To examine the extent of awareness and the rate of adoption of mobile banking services among college students in urban areas.
2. To measure user satisfaction with mobile banking based on speed, security, and usability.
3. To examine the impact of digital literacy and trust on mobile banking adoption by students.
4. To identify key challenges and concerns faced by students in using mobile banking apps.
5. To provide suggestions for improving mobile banking experiences for the youth segment

Research Methodology

Research Design

This study adopts a descriptive research design with a quantitative approach to evaluate the adoption and satisfaction levels of mobile banking among college students in urban areas. Primary data was collected through a structured survey administered to student respondents.

Area of Study

The research was conducted among college students in Mumbai, a region characterized by a dense concentration of educational institutions, advanced digital infrastructure, and high mobile banking penetration.

The study focuses on students enrolled in undergraduate and postgraduate programs across disciplines such as commerce, management, and technology.

Population and Sampling

The target population comprises **college students aged 18–30** who actively use mobile banking applications.

- **Sampling Method:** *Convenience sampling* was employed due to ease of access to students within various institutions.
- **Sample Size:** A total of **143 respondents** were selected for the study to provide a representative view within a limited timeframe.

Data Collection Methods

- **Primary Data:** Collected through a **Google Form questionnaire**, consisting of both closed-ended and Likert scale-based questions. The survey explored various dimensions including frequency of use, satisfaction, security concerns, app usability, and challenges.
- **Secondary Data:** Gathered from reports and publications by RBI, India FinTech Forum, GSMA, academic journals, and government portals to support literature and contextual analysis.

Limitations of the Study

- The study is limited to urban college students in Mumbai and may not reflect patterns in rural or semi-urban areas.
- As a self-reported survey, results are subject to personal bias and perception-based variability.
- Sample size will be 143 respondents.
- The use of convenience sampling may limit generalizability, although the sample was selected to ensure diverse representation.

Data Analysis and Interpretation

The collected data of 143 respondents has been analyzed and presented through Pie Charts and Bar Graphs.

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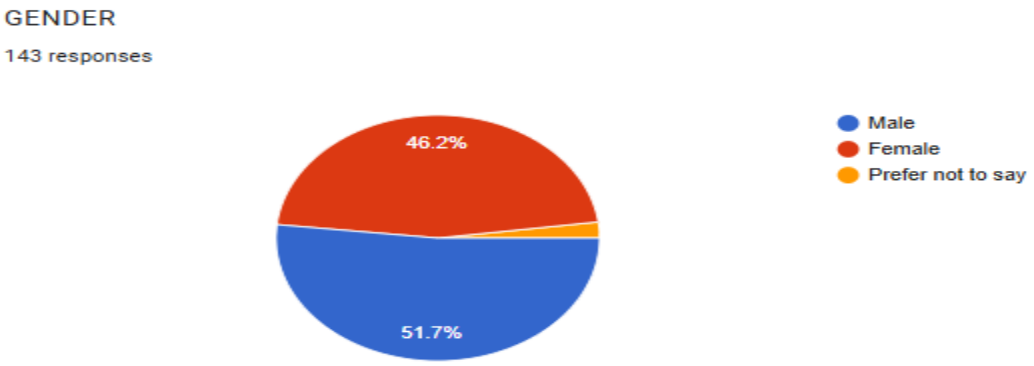
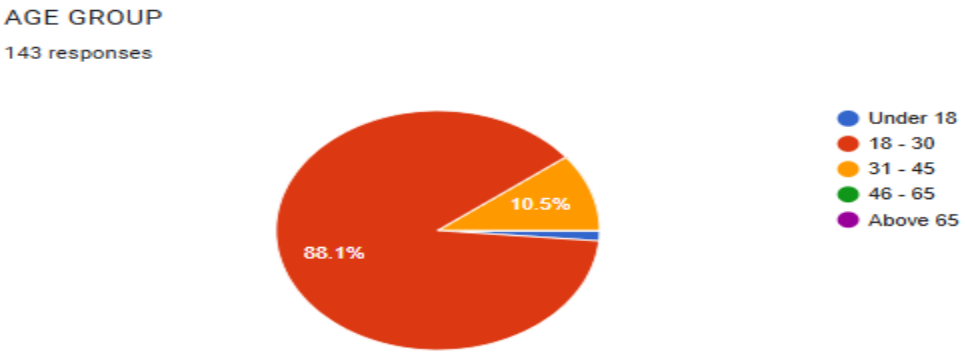
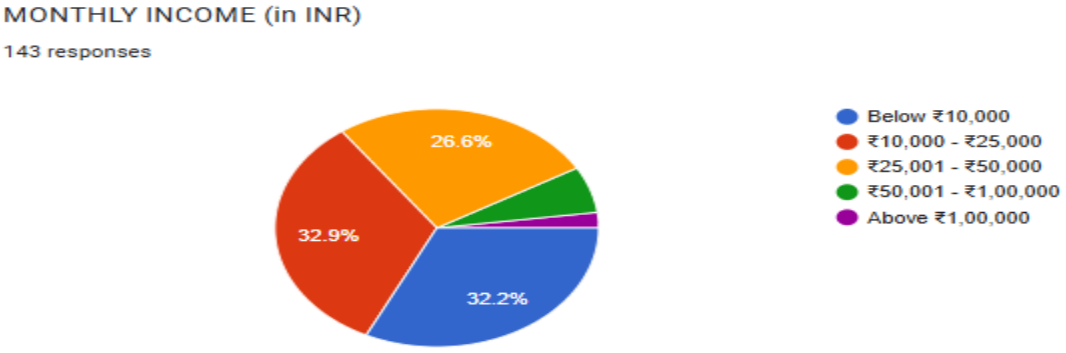


Out of 143 respondents, 51.7% were male and 46.2% were female, showing a fairly balanced representation. This suggests that mobile banking adoption is not significantly influenced by gender in urban student populations.



Among the 143 respondents, 88.1% were aged 18–30 years, confirming that mobile banking is predominantly adopted by the youth. This indicates that the younger generation is more comfortable with digitalization and mobile-based financial services.



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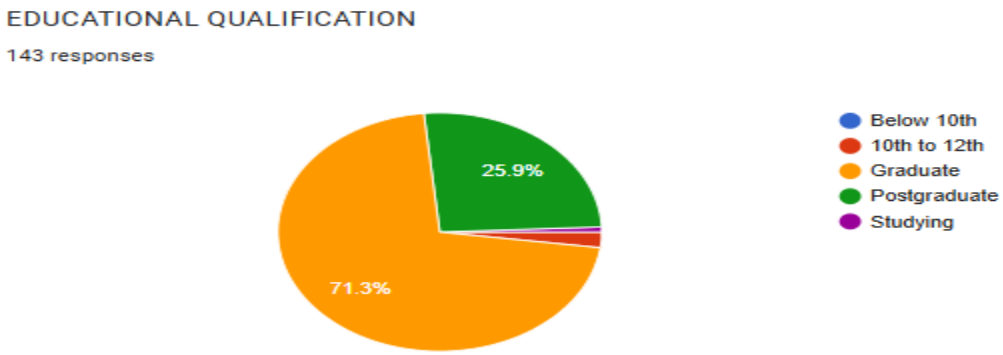
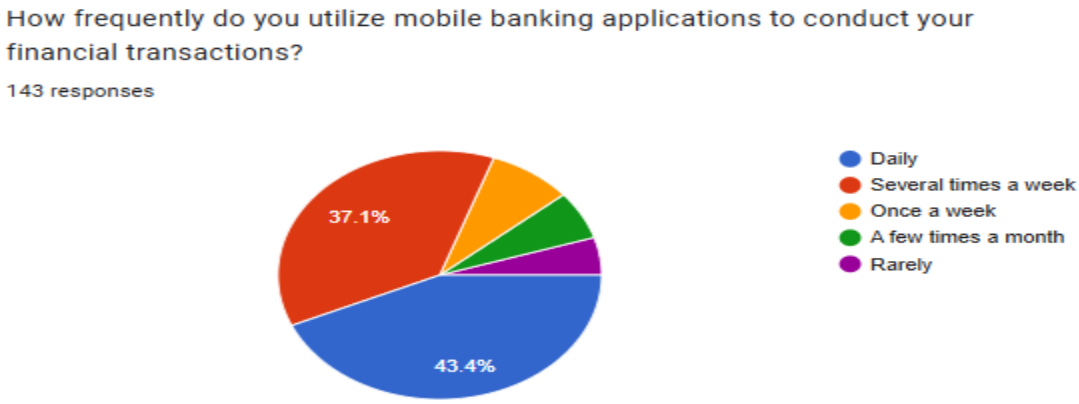
Among the 143 respondents, 32.2% of respondents had monthly income below ₹10,000, and 32.9% of respondents had monthly income from ₹10,000 to ₹ 20,0000, this indicating they are likely students or early-stage earners. Despite lower income levels, their high engagement with mobile banking highlights the accessibility and affordability of digital finance tools.



Among the 143 respondents, 71.3% of respondents are Graduate & 25.9% of respondents are Post Graduate.



Among the 143 respondents, Approximately 80.4% of students use mobile banking daily or several times a week. This high frequency indicates that mobile banking has become an integral part of their routine financial activities.

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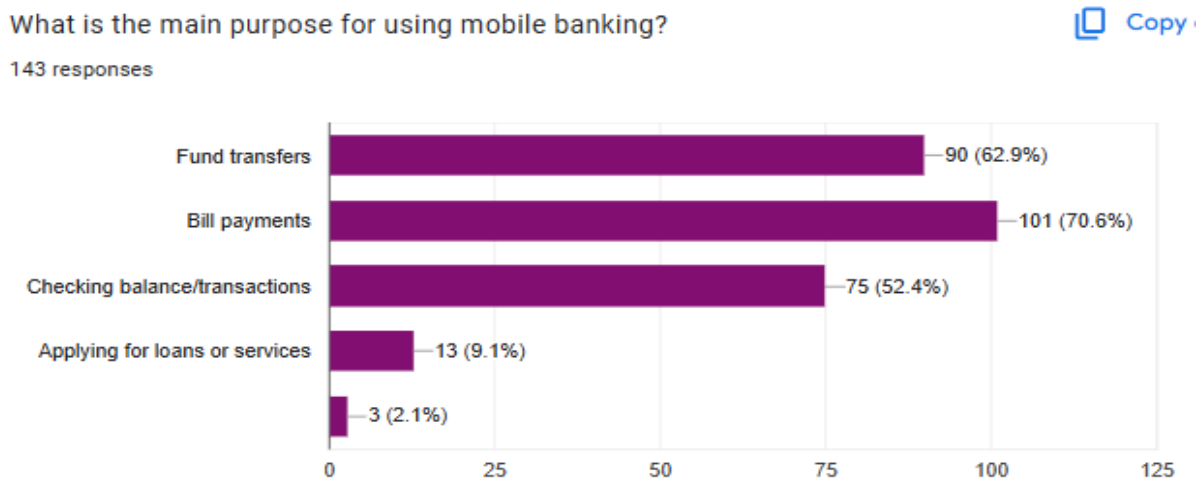
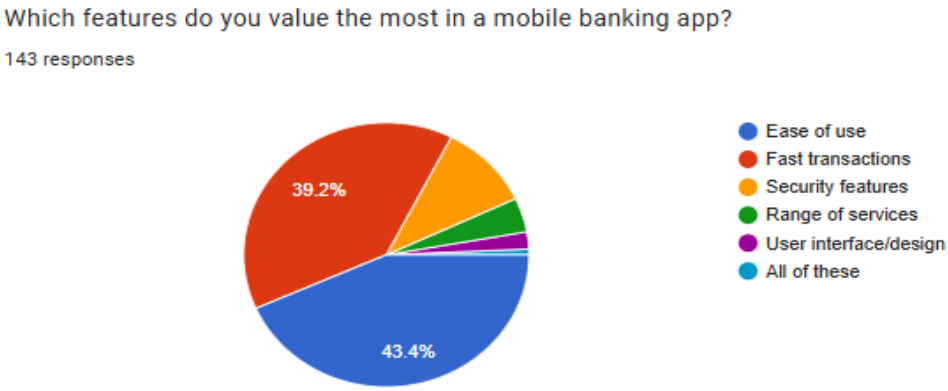


Most respondents reported using mobile banking for fund transfers, bill payments, and checking balances. This demonstrates that students rely heavily on mobile apps for basic but essential banking functions.



Among the 143 respondents, Ease of use (63 responses) and fast transactions (56 responses) were the top-rated features. This reflects that students prioritize speed and simplicity, likely due to their multitasking digital lifestyles.

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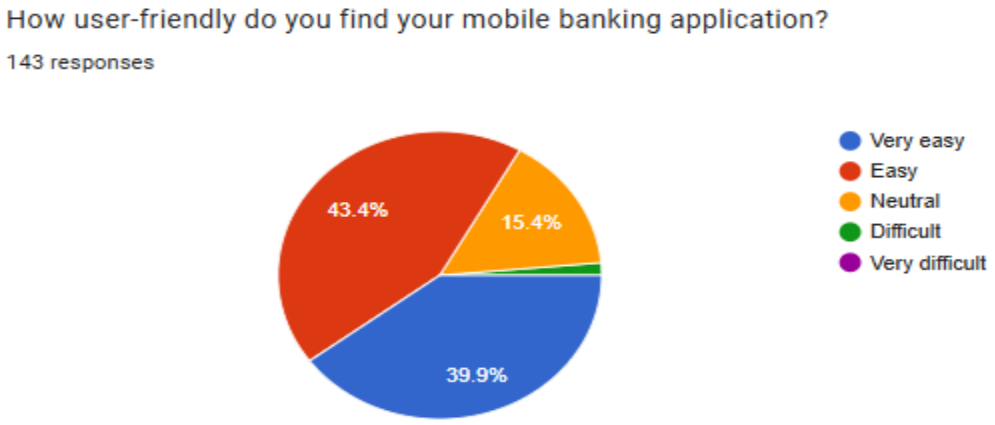
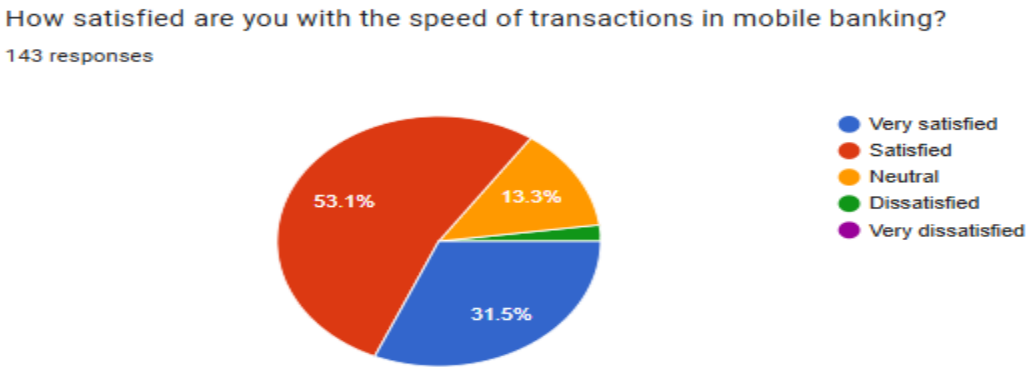


Among the 143 respondents, About 84% of respondents rated their mobile banking app as “Easy” or “Very Easy” to use. This indicates strong alignment between app design and user expectations.



Among the 143 respondents, about 85% of respondents are satisfied or very satisfied with transaction speed in mobile banking. This indicates that speed is a key strength and positively impacts user experience among college students.

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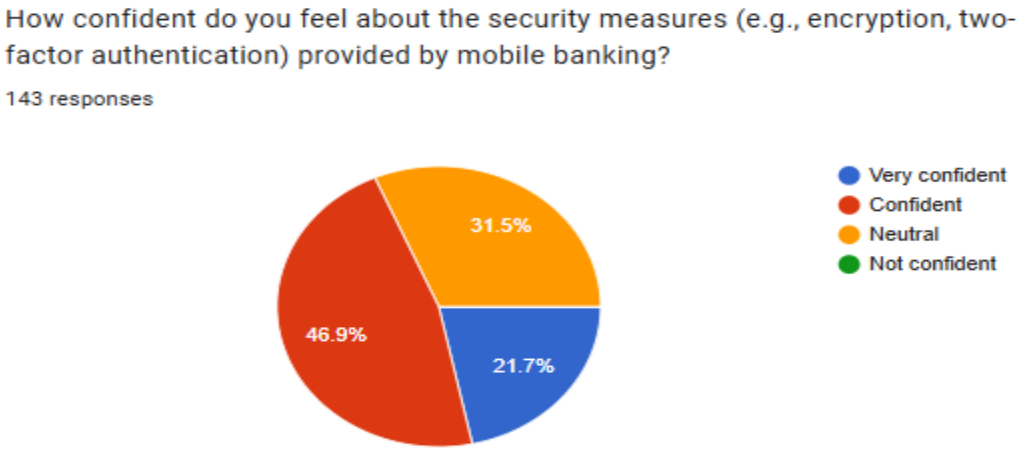
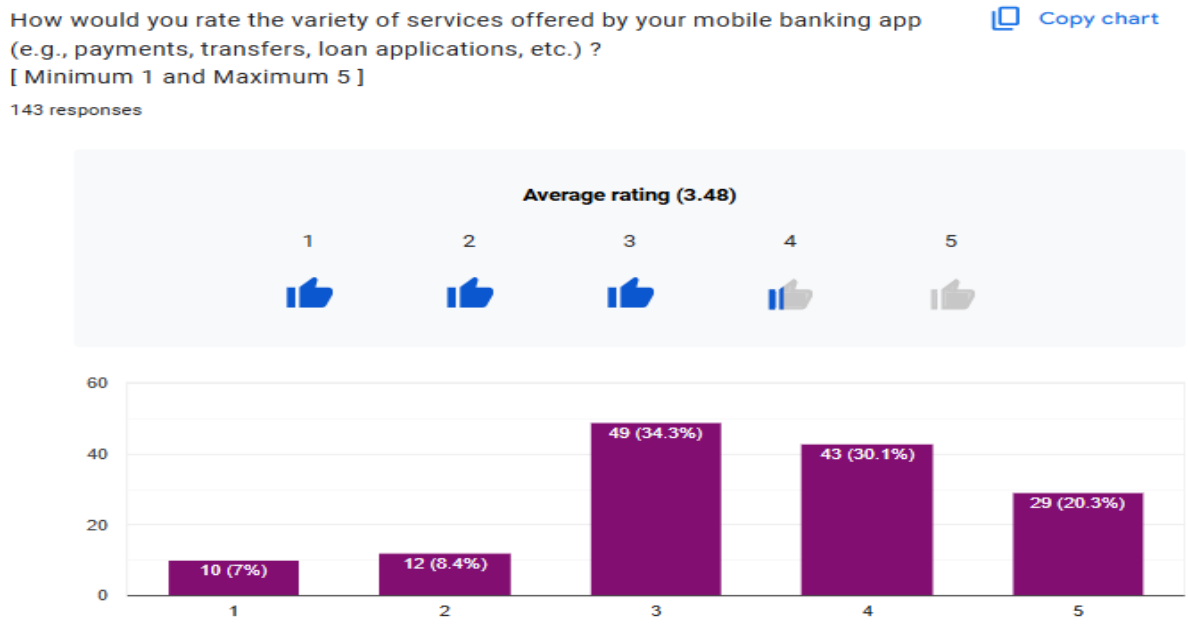
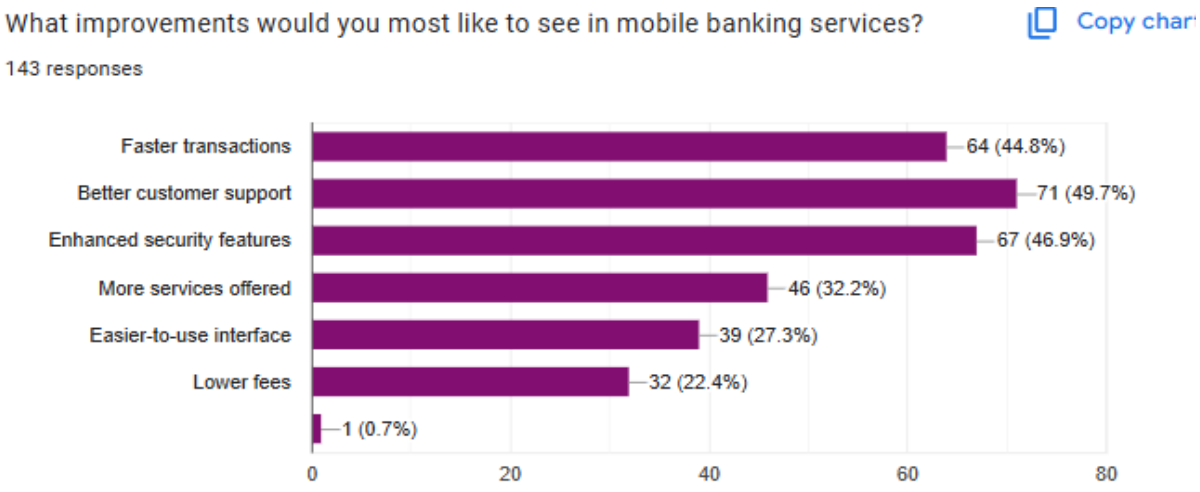


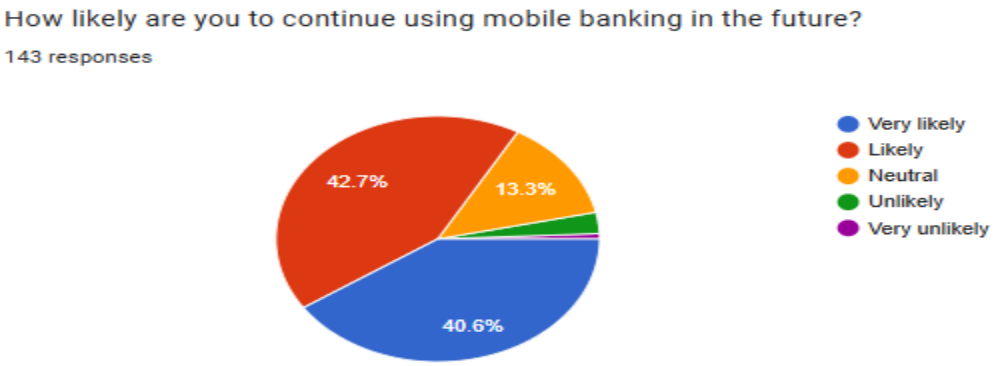
About 68.6% of respondents feel confident or very confident about the security of mobile banking apps. However, 31.5% remain neutral, suggesting the need for better awareness and transparency around security features.



The average rating is 3.48, with most students rating their app between 3 and 4. This indicates a moderate level of satisfaction, with room to expand offerings like investments, insurance, or loans.



Students most want better customer support (49.7%) and enhanced security features (46.9%). Other key asks include faster transactions and more services, revealing user demand for more robust digital platform.



About 83.9% of students said they were “Likely” or “Very Likely” to continue using mobile banking in the future. This shows a high level of satisfaction and sustained trust in digital financial platforms.

Findings

1. A significant 80.5% of college students use mobile banking daily or several times a week, indicating high adoption.
2. Fund transfers, bill payments, and balance checks are the most common reasons students use mobile banking.
3. Ease of use (44%) and fast transactions (39%) are the most valued features among mobile banking users.
4. Over 83% of respondents found their banking apps easy or very easy to use, showing strong user interface satisfaction.
5. 68.6% of students trust the security features of mobile banking apps, yet a sizable 31.5% remain unsure.
6. A majority (84.6%) are satisfied with transaction speed, reinforcing the efficiency of digital platforms.
7. The average rating for variety of services offered by apps was 3.48/5, reflecting moderate expectations being met.
8. Students express a strong desire for better support (49.7%), stronger security (46.9%), and faster service (44.8%).
9. Most students (over 80%) intend to continue using mobile banking in the future, showing long-term trust.

Conclusion

This study reveals that mobile banking has become an essential financial tool among urban college students, with over 80% using it regularly. Students primarily rely on mobile apps for routine services like fund transfers, bill payments, and balance checks. Key strengths include ease of use and fast transactions, which significantly contribute to user satisfaction.

However, the study also highlights concerns related to technical issues and inadequate customer support, with less than half of the respondents finding issue resolution easy. While 68.6% of users express confidence in app security, a notable share remains uncertain, pointing to the need for stronger communication on safety features.

Mobile banking has helped reduce dependency on cash, supporting India’s digital financial goals. Yet, usage of value-added services like loans or investments remains low, indicating untapped potential. To enhance

engagement, service providers should improve support systems, build trust, and introduce more youth-oriented financial features.

Suggestions

1. Only 47.6% found issue resolution easy banks should offer quicker help via chatbots and simple complaint systems.
2. With 68.6% confident in app security, better education on safety features can increase overall trust.
3. Frequent app issues reported by users highlight the need for regular updates and smoother performance.
4. Low usage of advanced services calls for student-focused tutorials, webinars, and campus sessions.
5. Add tools like budget planners, micro-savings, and fee payment options tailored for students.
6. As 83% find apps easy to use, developers should maintain clean design while adding new features.
7. Regularly gather and apply feedback to improve services based on user needs and trends.

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MARKETING CHALLENGES IN INDIAN TRADITIONAL HANDICRAFTS AND AESTHETIC VALUE

Dr. V. Pothigaimalai, Associate Professor, Dr. V. Pattammal, Head & Associate Professor, Department of Business Administrator, Dr. S. Geetha, Assistant Professor, Department of B. B. A. S. T. E. T. Women's College (A), Mannargudi.

ABSTRACT

The handicrafts sector is important for the Indian economy as it is one of the largest employments generators and accounts for a significant share in the country's exports. The state and regional clusters contribute significantly to handicrafts export. The Indian handicrafts industry is fragmented, with more than seven million regional artisans and more than 67,000exporters/export houses promoting regional art and craftsmanship in the domestic and global markets. Handicrafts is one of the key export segments of Indian trade faced with several problems such as unorganized marketing and inadequate market information; inadequate support mechanism for product development; power interruptions and other infrastructural deficiencies inadequacy of raw material at appropriate prices; lack of mechanism for dispersal of technology or enhancing productivity; final finishing and lack of investment for fulfilling international requirements and a general poor image of the country as a supplier of quality goods with consistency.

KEYWORDS: Handicrafts, Export, Technology, Deficiencies, Requirement and Development

INTRODUCTION

Despite fast-paced technological and social evolution, crafts continue to be deeply embedded in the Indian way of life. Unlike in the West, where crafts are luxury art forms, in India they serve as a primary livelihood for many, especially in rural communities. Handicrafts, made by skilled artisans, embody both individual creativity and centuries of cultural tradition. From simple clay items to intricately designed jewelry, these crafts serve various functions—from religious rituals to decorative purposes—and carry emotional and historical significance.

Crafts in India fall into three broad categories:

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There are three main classifications of crafts:

- Folk Crafts
- Religious us crafts
- Commercial crafts

Bihar Folk Embroidery:

People for their personal use, or for a limited client base create folkcrafts. Folk embroideries done by the village women folk of India are a good example. There are craftsmen who are specialized in creating textiles or jewellery which meet the criteria set up by a particular group of people, usually a particular caste or community. They have their own distinctive designs and styles

Bronze lamp used for worship:

Religious crafts are developed around religious centers and themes. These craft items are connected with religious institutions and relevant ceremonies. Various religious places in India are specialized in particular craft items. For example, Varanasi and Kanchipuram in Tamandu specialize in weaving clothes for religious ceremonies, particularly silk materials. Similarly, Puri in Odisha, which is a big pilgrim center, is connectedwith crafts like Pat Charita- a painting on cloth and wood and stone carvings. Specializedcraftsmen of a particular group who are specialized in a particular skill and who can completelymaster the craft do commercial crafts. They even have sub groups, which work for particulargroups, and their tools and techniques may vary. The Weavers, the Dyers, the Printers, theGoldsmiths and the Carpenters are some of the commercial craftsmen.

II. REVIEW OF LITERATURE

Being a recent move, there have been various researches on different aspects of the initiative ranging from the economical to social and ethical dimensions. Some of these researches retrieved through internet searches have been reviewed here.

Subrahmanyabala (2019) in his study made an important point that the focus of every nation especially India must be the collaboration of ancient art with the modern technology and strengthening of financial infrastructure support in order to make the Small and medium industry grow internationally. This leads in generating employment for the nation with that it would be a tough competition to the international market and improve the national income. Further author says even though the small and medium industry suffered due to globalization but this industry has potential to provide numerous benefits to local as well as to foreign market in terms of growth of units, employment, output and exports.

Shetty (2019) in his study has mentioned that it has become easier for the consumers to buy their handicraft items especially gift items and for manufacturers or artisans to reach out to the consumers where the modern facilities like virtual shops and business to business buying is possible. This modern technology has created business directories in order to meet the demand of the consumers and outline presences of handicrafts. Further states that if such technology reaches to every manufacture the middlemen will not exploit any of the artisans. Government of India need to indulge them in this for stopping unfair trade practices.

Arindam (2020) also is in opinion that the sector of handicraft has potential of economic improvement without any effect on sustainability. He further identified that handicraft will play pivot role in strengthening the cultural identity, heritage preservation which contributes to the overall development of the national economy with that author states that handicraft sector provides opportunities for entrepreneurs, creates jobs for workers, brings foreign currency to the domestic country through promoting exports and creates demand for the artisans. Sudha, V. and Krishnaveni, M. (2012). SMEs in India: Importance and Contribution. Lack of market awareness is the main obstacle for any village enterprises to put up their products in urban markets.

Handicrafts Exports from India:

The handicrafts sector is important for the Indian economy as it is one of the largest employment generators and accounts for a significant share in the country's exports. The state and regional clusters contribute significantly to handicrafts export. The Indian handicrafts industry is fragmented, with more than seven million regional artisans and more than 67,000 exporters/export houses promoting regional art and craftsmanship in the domestic and global markets.Handicrafts is one of the key export segments of Indian trade faced with several problems suchas unorganized marketing and inadequate market information; inadequate support mechanism forproduct development; power interruptions and other infrastructural deficiencies; inadequacy ofraw material at appropriate prices; lack of mechanism for dispersal of technology for enhancing productivity; final finishing and lack of investment for fulfilling international requirements and a general poor image of the country as a supplier of quality goods with consistency. The Indian handicraft industry considered to be small scale and cottage sector helps to solve social andeconomic problems of the artisans, by providing employment to over 70 lakhs artisans and morethan 67,000 exporters / export houses promoting regional art and craftsmanship in the domesticand global markets. This includes a large number of women and people belonging to weakersections of the society. The industry is highly labour intensive and decentralized, being spread allover the country in rural and urban areas. Many artisans are engaged in certain crafts work onpart-time basis. Handicraft is a sector that is still explored from the point of view of hidden potential areas.

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EXPORTS AND INDUSTRY STRUCTURE

India's handicrafts sector is labor-intensive and widespread, employing millions including women and underprivileged communities. It operates primarily as a cottage industry and lacks centralized organization. Though contributing significantly to exports, challenges like lack of market intelligence, poor infrastructure, and unorganized operations prevent full realization of potential. Craft pockets need institutional support to compete globally, particularly with countries like China and Thailand.

India's handicraft exports were valued at US$ 3.8 billion in 2018-19, with key markets including the US, UK, UAE, and Germany. Categories like woodware, embroidered textiles, and imitation jewelry top export charts. The Export Promotion Council for Handicrafts (EPCH), under the Ministry of Textiles, plays a central role in marketing and promotion efforts.

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MARKETING MIX IN HANDICRAFTS

Handicrafts have an expanding market in developed countries. Market research into crafts is negligible, if not non-existent. New trends and designs, new integral ways to feel the pulse of the market need to be determined and disseminated.Marketing touches everyone life. Marketing involves a large number of activities, includingmarketing research,product development, distribution, pricing, advertising, and personal selling,sales promotion, packaging and branding. Marketing combines several activities designed tosense, serve and satisfy consumer needs while meeting the goals of the organization. Handicraftunits, which are mostly run by individuals with sole proprietary form of organization can't affordto have separate and well-organizedmarketing system. The artisan cum-proprietor of the unitlooks after all the functions with the help of family members.. The role of market research and explorationwith appropriate marketing strategies assumes critical importance. An import data analysis ofhandicrafts and giftware in potential countries will help determine the size and character ofdifferent craft markets across the globe. The important marketing aspects are discussed under theheads of Product, Price, Place, Promotion.

Product: A product is a set of tangible and intangible attributes, including packaging, color, price, manufactures prestige, retailers prestige, and manufacturer and retailer& services, whichthe buyer may accept as offering want satisfaction.

Pricing: Price is a measure of what one must exchange in order to obtain a desired good or service. Price is the monetary expression value and is the focal point of the entire exchange

process. Historically, prices have been set by buyers and sellers negotiating with each other. Sellers would ask for a higher price than they expected to pay. Through bargaining they would arrive at an acceptance price. Setting one price for all buyers is relatively modern idea.

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Place: Distribution is concerned with the activities involved in transferring goods from producers to final buyers and users. It includes the physical activities, such as transporting,storing goods and the legal, promotional activities for transferring ownership. The artisansdepend mostly upon master craftsmen, dealers and co-operative societies for disposal of their

finished products.

Promotion:

Corporate houses and multi-national companies may be urged and facilitated to adopt andencourage crafts for the gifts they distribute. An important segment of market that needs to besystematically promoted is for corporate houses with customized logos for giveaways by themfor corporate clients.

GOVERNMENT INITIATIVES

Various schemes aim to uplift the sector:

- **Baba Saheb Ambedkar Hastshilp Vikas Yojana** – Encourages artisan mobilization, skill and design enhancement.
- **Marketing Support Scheme** – Promotes craft visibility through events and financial assistance.
- **Design & Technology Upgradation** – Focuses on modernization via training and expert partnerships.
- **Export Promotion Scheme** – Aids in design innovation, marketing, and artisan welfare.
- **Research and Development Scheme** – Gathers feedback and data to improve production and working conditions.
- **Bima Yojana** – Provides life insurance to registered artisans.
- **Training Projects** – Enhance skills and ensure transmission of traditional expertise.

Despite these, implementation is often poor due to a lack of accurate artisan databases and grassroots awareness.

TYPES AND CURRENT STATUS

India, with its vast linguistic and cultural diversity, offers a wide array of craft forms:

- **Textile Crafts**: Embroidery, block printing, batik, kalamkari
- **Metal and Jewelry**: Brassware, silver ornaments, and stone-set pieces
- **Woodwork**: From carved toys to ornate furniture
- **Stonework**: Intricately carved decorative pieces
- **Glass and Ceramics**: Blown-glass and handcrafted ceramic items

Crafts are either **functional** (everyday use) or **decorative** (aesthetic appeal), and span both rural and urban markets.

SWOT ANALYSIS

Strengths

- Low production cost
- Unique designs and traditions
- Flexibility for small-batch orders

Weaknesses

- Inconsistent quality
- Limited marketing strategies
- Poor infrastructure and delayed deliveries

Opportunities

- Increased interest from global consumers
- E-commerce and direct marketing potential
- Demand from retail chains abroad

Threats

- Superior quality and R&D by competitors
- Better export support from rival countries
- Stringent international trade standards

CONCLUSION

The Indian handicrafts industry has a strong socio-economic foundation but suffers from fragmentation, underutilization of government schemes, and low global competitiveness. Despite being a sector rich in tradition and employment potential, it struggles with limited awareness, poor organization, and infrastructural bottlenecks. With appropriate reforms, better promotional strategies, and technology integration, Indian handicrafts can emerge as a global leader in artisan goods.

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AN ANALYTICAL STUDY OF HOW INDIA'S ORAL AND TEXTUAL HERITAGE IS REPRESENTED ON DIGITAL PLATFORMS FOR GEN Z's CONSUMPTION

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Shree L R Tiwari Degree College of Arts, Commerce and Science

Abstract

India's oral and textual traditions have shaped its cultural identity for centuries, preserving stories, songs, and knowledge through generations. In today's digital age, this heritage faces both fresh challenges and new possibilities as it finds its way onto online platforms for Generation Z, considered as India's first truly digital-native audience. This study examines how folk tales, epics, and classical literature are adapted and shared through YouTube, podcasts, social media, and streaming services. Relying entirely on secondary sources, the research analyses how these traditions are curated for young audiences, the creative strategies involved, and the challenges of maintaining authenticity. Findings indicate that while digital tools expand access and revive interest in cultural roots, they can also risk oversimplifying complex narratives. This study underscores the importance of balancing modern, engaging formats with cultural depth, offering suggestions for educators, content creators, and policymakers to help India's heritage continue to resonate with the next generation.

Keywords: *oral tradition, textual heritage, Generation Z, digital media, cultural continuity, India, storytelling*

Introduction

India is renowned for its rich and varied legacy of textual heritage and oral traditions. From ancient Vedic chants and epics like the *Mahabharata* and *Ramayana* to regional folk tales, ballads, and devotional songs, India's cultural continuity has depended on both spoken and written forms of storytelling (Ramanujan, 1991; Thapar, 2003). Historically, these traditions were passed down orally through generations or preserved in handwritten manuscripts.

However, in the 21st century, rapid digitization and the rise of the internet have transformed how cultural content is produced, consumed, and shared. Generation Z, defined roughly as individuals born between 1997 and 2012, represent India's first truly digital-native generation. They interact with the world through smartphones, short videos, social media feeds, and streaming content, favoring formats that are concise, visually engaging, and interactive.

This shift raises an important question: How is India's rich oral and textual heritage being adapted and represented on digital platforms to reach Gen Z audiences? This study attempts to analyze this emerging intersection of heritage and technology through secondary research.

Literature Review

India's oral and textual heritage has been the subject of extensive academic scholarship. Ramanujan (1991) highlights how folktales thrive on local adaptations and oral transmission. Thapar (2003) discusses the historical role of storytelling in building collective memory and social identity. Sen (2012) argues that modernization and globalization have disrupted traditional channels of cultural transmission, posing new challenges for preserving intangible heritage.

Recent studies suggest that digital technologies offer powerful tools for revival and dissemination. Kaul (2023) explores how YouTube channels and podcasts adapt myths and folk stories for urban youth, blending animation, audio drama, and explainer formats. Sharma and Singh (2021) highlighted that Instagram and Meme Culture have been instrumental in increasing the popularity of folk tales and classical poetry in short, relatable snippets. Bhattacharya (2022) examines how streaming platforms incorporate mythic themes into modern narratives to appeal to younger audiences.

Reports from IAMAI (2023) and EY-FICCI (2023) reveal that Gen Z prefers short-form videos, podcasts, and multilingual storytelling over traditional print. However, scholars caution that oversimplification, loss of linguistic nuance, and algorithm-driven sensationalism risk diluting the authenticity of these traditions (Chatterjee, 2020).

Methodology

This study relies entirely on secondary data analysis. No primary surveys or interviews were conducted. Relevant data was collected through:

- Academic books, peer-reviewed journal articles, and cultural studies reports.
- Published case studies of digital initiatives such as *Epified* (YouTube channel), *Indian Noir* (podcast), and Instagram handles like *@PoetryIndia*.
- Industry reports from IAMAI, EY-FICCI, and UNESCO.
- Reputable media articles covering the representation of heritage on OTT platforms and social media.

The data was analyzed thematically to identify:

1. The oral and textual traditions adapted for digital media.
2. The formats and strategies are used to target Gen Z.
3. The challenges and gaps discussed in the literature.
4. The opportunities highlighted for sustaining cultural continuity.

Significance of the Study

This research contributes to the growing conversation on digital cultural preservation. By mapping how India's intangible heritage is reimagined for Gen Z audiences, it provides insights for educators, policymakers, content creators, and cultural institutions aiming to bridge traditional knowledge with contemporary youth culture. It highlights the potential of digital tools to democratize access to folk stories and classical literature while also warning against superficial or commercialized adaptations.

Scope of the Study

The scope of this study is specifically focused on how India's rich oral and textual heritage is represented and adapted on modern digital platforms such as YouTube channels, podcasts, Instagram pages, and OTT streaming services. It examines how these formats reshape folk tales, classical narratives, and regional myths to align with the viewing and listening habits of Generation Z audiences in India. The study draws exclusively from secondary sources- including published literature, scholarly analyses, verified digital case studies, and reputable industry reports to explore emerging trends and patterns in this space.

However, the study does not include primary fieldwork such as audience interviews, surveys, or direct quantitative data collection. It also does not examine non-digital forms of cultural expression such as live performances, stage recitations, or print anthologies of folk literature. Finally, this research remains limited to the Indian context, without extending its analysis to generational comparisons with older cohorts or cross-cultural studies involving other countries. This defined scope ensures the study remains sharply focused on the intersection of India's heritage, digital platforms, and Gen Z consumption patterns.

Sources of Data Collection

This study relies exclusively on secondary data, gathered from diverse and credible sources, each selected for its direct contribution to understanding how India's oral and textual heritage is adapted, circulated, and consumed on digital platforms by Generation Z audiences. By combining classic scholarship with the latest industry reports and real-world digital examples, this research builds a comprehensive picture of the intersection between heritage and youth media habits in India.

1. Peer-Reviewed Books and Journals

Ramanujan, A. K. (1991) *Folktales from India: A Selection of Oral Tales from Twenty-Two Languages* This foundational work remains one of the most cited collections showcasing India's remarkable diversity of oral storytelling. Ramanujan did not simply compile stories, he explained how folktales are shaped by local contexts, languages, and performance traditions. For this study, Ramanujan's work provides essential background on the original forms and functions of oral narratives before they were ever digitized. This collection demonstrates how folktales adapt to regional beliefs, social norms, and audience interactions, showing that oral narratives are never static but fluid, shaped by each storyteller's style and the listeners' responses. This depth is crucial for understanding what might be lost or gained when these same stories are repackaged for digital audiences today. For this study, Ramanujan's work serves as a baseline for comparing traditional, community-based storytelling with its modern digital counterparts, such as short animated videos on YouTube, audio series, or Instagram snippets. By contrasting the layered, locally rooted versions with today's algorithm-driven, bite-sized formats, the study highlights how digital platforms preserve the appeal and reach of folktales but also inevitably reshape their narrative style, language, moral lessons, and emotional tone to match Gen Z's fast-paced, mobile-first media habits. By comparing these traditional versions with their online adaptations, such as animated YouTube videos or podcast retellings, the study highlights how digital formats both preserve and reshape moral themes, narrative style and language to cater to Gen Z tastes.

Thapar, R. (2003) *Early India: From the Origins to AD 1300* Romila Thapar's extensive historical analysis details how India's ancient texts from Vedic hymns to epics like the

Mahabharata and *Ramayana* and early Buddhist and Jain texts evolved through both oral recitation and early manuscript culture. Her work helps frame how oral performance and written transmission have always coexisted, often with blurred boundaries. This context supports the study's exploration of how today's digital platforms continue this duality by blending spoken word (podcasts, storytelling videos) with textual snippets (Instagram poetry, meme quotes) for digital-native audiences.

She shows how storytellers, bards, temple singers, and village performers played vital roles in carrying these narratives across generations, often adapting plots, characters, and moral lessons for local audiences. This fluid coexistence of oral performance and written tradition is central to India's cultural memory and directly mirrors what happens today when folk stories are retold on podcasts, YouTube explainers, or short-form videos, often mixed with on-screen text or subtitles for digital audiences.

Thapar's analysis provides this study with the historical context to argue that India's heritage has never been static. Instead, it has always relied on new technologies, from palm leaves to printing presses to reach new audiences. Today, digital platforms are simply the latest stage in this long continuum. This perspective helps the study examine whether modern digital retellings, algorithm-driven feeds, and viral trends are a natural evolution of India's oral-textual duality or whether they risk flattening the complexity and local depth these stories once carried.

Sharma & Singh (2021) — *Mythologies on Reels: Indian Folk Narratives and Digital Meme Culture*
This peer-reviewed article is a pivotal source that bridges traditional folklore studies with contemporary digital youth culture. Sharma and Singh examine how age-old Indian folk myths — including local legends, regional epics, and moral tales once passed down orally or through written folktale collections — are now being revived and circulated in new forms, particularly through short-form video platforms like Instagram Reels and TikTok.

The authors provide detailed case examples of how mythological figures such as Karna, Draupadi, or regional trickster characters are reimagined as humorous memes, trending audios, or short animated reels that can be easily shared and remixed by Gen Z users. They note that creators often adapt the original plotlines or moral lessons to make them relatable to modern social issues, college humor, or pop-culture references. For example, they highlight how ancient moral fables are turned into short, comedic skits that comment on topics like family dynamics, politics, or everyday frustrations familiar to urban youth.

This article is especially important for the present study because it directly illustrates how India's oral and textual heritage is being detached from its original contexts and reinserted into digital youth culture. It highlights both the opportunities-greater reach, revival of forgotten tales, youth engagement and the risks, such as trivialization, loss of cultural nuance, and the commercial pressures of viral content creation.

The findings from Sharma and Singh thus provide a clear lens for this study to critically evaluate whether digital representations of folk myths on platforms like Reels, TikTok, and memes strengthen cultural continuity by making old stories relevant, or whether they dilute the deeper layers of meaning that oral or textual traditions originally carried. This link between theory (folklore studies) and practice (digital remixes) is central to understanding the complex dynamics of heritage preservation and transformation in the Gen Z era.

Kaul, A. (2023) — *Digital Folk Revival in Urban India: Podcasts, YouTube, and the New Oral Storytellers*
Kaul's recent work provides a valuable look at how traditional Indian folk tales and classical stories are being revived in cities through modern digital storytelling. Focusing on young urban creators, Kaul analyzes how podcasts, YouTube

channels, and short-form videos have become new spaces for sharing folk narratives that were once told in village squares or family gatherings.

Through detailed examples, Kaul shows how creators combine voice acting, dramatic narration, background soundscapes, animation, and interactive visuals to make ancient stories feel fresh and immersive for Gen Z audiences who consume content mostly on smartphones. The study also highlights how these storytellers use social media marketing, hashtags, and algorithms to reach wider audiences, often shaping which tales gain popularity and which stay hidden.

Kaul's insights are crucial for this research because they reveal how digital tools can breathe new life into India's oral heritage, while also raising questions about authenticity, selective storytelling, and the influence of trending formats on cultural depth. By examining these digital folk revival efforts, this study can better understand the balance between cultural preservation and adaptation in a youth-focused, online environment.

2. Industry and Institutional Reports

EY-FICCI (2023) ***Media and Entertainment Industry Report 2023***

This annual flagship report provides extensive quantitative data on India's media landscape, with sections dedicated to how Gen Z consumes content across OTT platforms, YouTube, social media, and podcasts. It includes metrics on short-form video growth, language preferences, and device usage. For this study, the report helps contextualize why creators choose certain formats; for example, why short, animated explainers work better than hour-long documentaries for Gen Z, or how regional language content is a growing trend in youth digital consumption.

A key insight from the report is that Gen Z prefers quick, visually engaging content they can access anytime on smartphones, which explains why formats like Instagram Reels, animated YouTube explainers, and snackable video series thrive while longer, text-heavy content struggles to hold their attention. For this study, these insights help explain why folk tales and traditional stories are increasingly reimagined as bite-sized videos, dubbed or subtitled in local languages, and marketed through youth-centric social media trends. Overall, the report provides crucial context for understanding the economic, technological, and cultural factors that shape how India's oral and textual heritage is adapted and monetized for Gen Z on digital platforms.

IAMAI (2023) ***Internet in India 2023***

The *Internet in India 2023* report, published by the Internet and Mobile Association of India (IAMAI), provides detailed breakdown of mobile-first habits, showing that smartphones remain the dominant device for streaming videos, listening to podcasts, and engaging with social media. The report also highlights how India's Gen Z prefers fast, data-light content, an insight that explains why folk tales and regional stories are now turned into short videos, reels, or quick audio clips that work well on mobile networks.

Another key point the report highlights is the strong rise in regional language users, showing why many creators adapt folk stories in local languages to reach wider youth audiences. It also notes that gaps in digital access and literacy still exist between urban and rural youth, reminding this study that not all Gen Z audiences can equally benefit from digitized cultural content.

By grounding this research in IAMAI's robust national data, the study situates India's digital folk revival within the real-world context of Gen Z's devices, habits, languages, and online reach — making it clear where there are new opportunities for cultural continuity, and where gaps remain.

UNESCO South Asia Regional Reports

UNESCO's reports add an international perspective on how intangible cultural heritage can be safeguarded using digital tools. For this study, these reports provide comparative examples, showing how India's digital folk revival aligns with or differs from other countries' efforts to make traditional knowledge youth-friendly through tech. It also helps the study reflect on what India can learn from international examples to ensure that its rich oral and textual heritage is not only digitized for Gen Z but done so ethically and meaningfully.

For this study, UNESCO's findings provide valuable comparative examples of how other South Asian nations are using technology to make traditional knowledge more accessible, especially to younger, tech-savvy generations. The reports also highlight common challenges such as copyright issues, community consent, and the risk of losing cultural depth when sacred or community-specific stories are made widely available online.

3. Digital Case Studies

Epified (YouTube Channel)

Epified is one of India's pioneering digital channels focused on transforming epics, myths, and history into short, animated stories. It has over a million subscribers and its videos are widely shared in schools and on social media. By analyzing Epified, the study shows how visual animation, voice-over storytelling, and historical context are combined to repackage complex narratives like the Mahabharata into 3-5 minute segments that Gen Z can watch on mobile devices, aligning with their preference for quick, visually engaging learning.

Indian Noir (Podcast)

Indian Noir illustrates the modern revival of the oral tradition through audio storytelling. The podcast blends classic horror and mythic motifs with contemporary production techniques such as suspenseful narration, immersive soundscapes, and serialized episodes. This case helps the study highlight how the listening culture, once deeply embedded in community storytelling, is reimagined for solo digital listening through headphones yet still carries echoes of the old village bard tradition.

@PoetryIndia (Instagram Handle)

This Instagram page curates bite-sized snippets of Indian poetry - from medieval mystic poets to modern verse, layered onto visually aesthetic posts and reels. This example demonstrates how textual heritage, traditionally read in anthologies, is now repurposed as shareable content that fits Gen Z's social media habits. The page also shows how followers interact through comments, remixes, and re-shares, effectively creating a participatory, digital poetry community.

4. Reputable Media Articles and Cultural Commentary

To add timely examples and real-world perspectives, the study refers to articles, cultural features, and opinion pieces from established publications:

The Hindu is well known for its in-depth reporting on India's rich artistic and cultural landscape. Its features and reports often illustrate how traditional practices adapt to new media environments. For instance, *The Hindu* has documented how classical dance performances, folk storytelling sessions, and regional music festivals have moved online through live-streamed shows and interactive webinars, particularly during the COVID-19 pandemic. Such reporting demonstrates how artists and communities innovate to sustain audience connections and preserve cultural continuity despite physical limitations.

Scroll.in serves as a valuable source for stories about independent digital creators who rework folk tales, epics, and oral histories for new-age platforms. Its cultural commentaries and interviews showcase how content creators use YouTube, Instagram, and OTT channels to make folklore accessible to younger audiences through short videos, animations, or hybrid formats like spoken word and memes. These articles highlight both opportunities and tensions: while digital storytelling invites creative reinterpretation, it also raises questions about fidelity to source narratives and the challenges of monetizing niche cultural content.

The Wire contributes critical analysis of how digitization reshapes the value and meaning of traditional knowledge. Its opinion pieces frequently address concerns about the commercialization of cultural heritage online. For example, articles explore how folk performances or ritual practices are packaged for clicks and sponsorships, sparking debates about the trade-offs between visibility, authenticity, and commodification in a profit-driven digital ecosystem.

Together, these media sources add context to the scholarly and industry reports, grounding the study in current examples and highlighting how audiences respond to this digitized heritage in real time.

Limitations of the Study

Dependence on Secondary Data: The study relies exclusively on existing sources; it does not include fresh audience surveys or field interviews.

Language Focus: Most examples are urban or pan-Indian; many hyper-local or tribal oral traditions still lack digital documentation.

Rapidly Evolving Platforms: Social media trends change fast; some case studies may become outdated quickly as platforms update algorithms and user preferences shift.

Conclusion

This research confirms that India's oral and textual heritage is undergoing a digital revival, driven by the creative efforts of YouTube storytellers, podcast hosts, meme curators, and OTT creators. While this expands the reach of traditional stories, it also raises concerns about loss of authenticity, simplification, and commercial pressures. Thus, to keep cultural traditions alive for Gen Z, digital mediums must balance engagement with depth, and popularity with preservation.

Suggestions

Based on the findings, the study suggests:

- Developing open-access, multilingual digital archives of folk stories and regional literature.
- Training regional storytellers and artists to use digital tools effectively.
- Encouraging collaborations between tech startups, cultural institutions, and educational platforms.
- Promoting policies that support fair monetization and credit for traditional knowledge holders.
- Integrating verified cultural content into EdTech and school curricula for Gen Z.

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"Physicochemical Quality Assessment of Biodiesel Synthesized Using Novel Zeolite Catalysts from Waste Cooking Oils: Compliance with EN 14214 and ASTM D6751"

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Abstract

This research explores the transesterification of waste cooking oils (WCOs) over two new heterogeneous catalysts: Sn-RH-Zeolite and K_2CO_3-CaO–Zeolite. The catalysts were rice husk ash-derived chemically modified zeolite and screened for catalytic performance, structural stability by FTIR, XRD, and TGA methods. Both the catalysts yielded over 93% biodiesel under optimized transesterification conditions. Sn-RH-Zeolite was a better catalyst due to its dual Brønsted and Lewis acid nature, successfully catalyzing higher oils containing free fatty acids in. In addition, after five cycles of reuse, it maintained over 70% activity. Initially very active, K_2CO_3-CaO-Zeolite quickly deactivated as a result of structural breakdown and potassium and calcium species leaching. Viscosity, acid value, iodine value, flash point, and FFA content are some of the key physicochemical factors that were evaluated in biodiesel produced from leftover sunflower and mustard oil. Every value was discovered to be within the parameters, vis-a-vis fuel quality and engine compatibility. The results show the potential of modified zeolite catalysts for future sustainable production of biodiesel from degraded feedstocks. Future research should be focused on regeneration of damaged catalysts, scale-up, and integration with waste valorization methods for enhancing circular bio-economy and cleaner energy processes.

Keywords

Biodiesel, WCO, SRZ, KCZ, Transesterification, Catalyst Reusability, Physicochemical Properties, ASTM D6751, EN 14214, FFA.

1 Introduction

The growing global demand for renewable fuel, coupled with environmental issues and dwindling fossil fuel resources, has promoted increasing interest in the application of biodiesel as an alternative. There are certain benefits to biodiesel, which is created by employing a catalyst to transesterify oils or fatty substances with alcohol (mostly methanol) have some advantages of biodegradability, low sulfur content, enhanced lubricity, and reduced greenhouse gas emissions. Waste cooking oils (WCOs), generated in large quantities by households and commercial units, are low-cost and eco-friendly. WCOs are generally high in free fatty acids (FFAs), water, and degradation products due to frequent heating and therefore are a difficult substrate for transesterification. High FFAs lead to soap formation with alkaline catalysts and reduced biodiesel yield and purity. To overcome these, heterogeneous catalysts, especially zeolite-based ones, are chosen because of the ease of catalyst separation, recyclability, and low environmental footprints. Zeolites are excellent for esterification and transesterification because of their large surface area, regulated acidity, and heat stability. This paper explores two novel zeolite catalysts: Sn-RH-Zeolite (rice husk ash and tin derived) for dual acidic functionality, and K_2CO_3–CaO–Zeolite (post-treated natural zeolite) for basic catalysis. These were screened using a series of WCOs sunflower, mustard, soybean, groundnut, palm, and sesame oil over various frying cycles to represent real-time degradation. Biodiesel quality was tested against EN 14214 and ASTM D6751 standards, taking into account significant parameters such as acid value, viscosity, iodine value, flash point, and FFA content. Apart from yield, focus was on ensuring the final fuel met international performance and

safety standards. Additionally, performance of the catalyst through several cycles was evaluated using FTIR and XRD to screen for structural integrity and stability. The research also explores the effects of oil type and degradation degree on the quality of biodiesel and the implications of choosing the right catalyst-feedstock pair. In using waste feedstocks and agro-residues as feedstocks for the synthesis of catalysts, the research supports green energy generation and circular economy principles. The results allow decentralized biodiesel systems that are adequate for resource-poor communities, facilitating environmental sustainability and energy security.

2.1 Materials

Various types of waste cooking oils (WCOs) collected from typical Indian residential kitchen settings. The oils were collected after being utilized for frying typical deep-fried foods such as puris (fried wheat bread) and pakoras (vegetable fritters). For the purposes of realistically mimicking home frying operations and for various degrees of degradation, oils were collected after various degrees of reuse:

First frying stage (fresh oil for one-time frying session)

Second fry process (reusing oil once after first fry)

Third stage of frying (oil used twice or more)

Every subsequent frying process brings it one step nearer to thermal degradation, leading to measurable changes in the makeup of the oil. In particular, the oil oxidizes, hydrolyzes, and polymerizes, with increased free fatty acid (FFA) content, viscosity, and degradation products such as peroxides and carbonaceous residues.

2.2 Waste Cooking Oil Pre-treatment

To ensure quality and removal of interfering impurities before the transesterification reaction, the WCOs were pretreated in three steps as follows:

Filtration Process

WCOs are typically accompanied by particulate matter such as food particle residue, charred residue, and carbonaceous deposits. These solids have the potential to deactivate the catalyst and clog the reactor system. The oils were therefore first left to stand in beakers or containers to allow coarse particles to settle. The supernatant oil was further filtered through multiple layers:

A coarse filter or a muslin to trap big impurities

Fine grade filter paper (Whatman No. 1 or equivalent) for additional purification

This step improved oil clarity, reduced catalyst fouling, and offered smooth flow throughout the reaction.

Moisture Evaporation (Heating)

Water in WCOs can induce hydrolysis of triglycerides, which subsequently produces FFAs and soap, particularly when basic catalysts are employed. Hot-plate or heating mantle and stirring were employed to heat filtered oil to 110°C for 30 minutes for removal of residual water. The temperature was ample enough to drive off water without affecting the molecular structure of the oil. Cool-down and room temperature and storage for subsequent use were employed after the oil was cooled.

Storage Procedure

Proper pretreated WCO storage is required to avoid re-contamination and oxidation. Dried and filtered oils were stored in glass, stainless steel, or HDPE tight, light-tight containers. For short-term storage, to avoid oxidative degradation, the containers were kept in a dark, cool, and dry atmosphere. For longer storage, oils were kept at 4–10°C under refrigeration. This process ensured oil stability, reduced peroxide formation, and ensured consistent feedstock quality for the biodiesel conversion process.

2.3 Catalyst Synthesis and Characterization

Two heterogeneous zeolite-based catalysts, Sn-RH-Zeolite and K_2CO_3-CaO-Zeolite, were synthesized and characterized based on previously reported methods [Mina and Jayshree, 2025]. The Sn-RH-Zeolite catalyst was synthesized from rice husk ash-silica, followed by tin impregnation to create bidentate acid sites, well-suited for transesterification and esterification reactions simultaneously. By contrast, the K_2CO_3-CaO-Zeolite

catalyst was synthesized using sequential acid-washed natural zeolite, followed by impregnation with potassium carbonate and calcium oxide to form basic active sites well-suited for low-FFA feedstocks.
Both the catalysts were distinguished by: FTIR, XRD, TGA -Detailed synthesis protocols and full characterization data are presented in the above study:

2.4 Transesterification Reaction Setup

A 250 mL round-bottom flask with a single neck was used as a batch reactor for conducting the transesterification reaction. Uniform blending and constant temperature were ensured by a magnetic stirrer with a heating plate. A reflux condenser was attached to the flask so that the evaporation of methanol during the reaction was prevented. 50 mL of preheated waste cooking oil was used in each experiment. Methanol was used in a molar ratio of 9:1- 15:1 (methanol to oil). The catalyst was kept constant at 3-4 wt.% of the weight of oil. The mixture was agitated at 650 rpm and heated at 60 ± 5 °C for 180 minutes

2.5 Post-Reaction Processing

On reaction, the resulting mixture was allowed to set before poured into a separatory funnel. The funnel was allowed to remain undisturbed for 3-4 hours to enable clean separation into two different layers.
The top layer was biodiesel (fatty acid methyl esters, FAMEs)
The bottom layer had glycerol, excess methanol, leftover catalyst, and soaps.
The biodiesel phase was then slowly harvested and washed multiple times with warm distilled water (45–50 °C) until the wash water was neutral (pH ≈ 7). The biodiesel was then dried in an oven (110 °C) for 4 hours to eliminate any residual water and methanol. The final biodiesel samples were then stored in clean, amber bottles for subsequent physicochemical analysis

2.6 Determination of Fuel Properties

The following major fuel parameters of the produced biodiesel ensured fuel-grade compatibility (ASTM International, 2020; European Committee for Standardization, 2012).

2.5.1 Kinematic Viscosity (ASTM D445)

Viscosity at 40 °C was determined using a Redwood Viscometer. The time taken by a pre-fixed volume of biodiesel to flow through a calibrated orifice was determined and converted into kinematic viscosity (mm^2/s).

2.6.2 Acid Value (ASTM D664)

To ensure full solubilisation, a 0.5 g sample of biodiesel was dissolved in 50 cm^3 of neutralized ethanol and then heated in a water bath. After cooling, phenolphthalein was used as an indicator to titrate the mixture with 0.1 M KOH. The amount of remaining acidic components in the sample is indicated by the volume of KOH utilized. This was used to determine the fuel purity by calculating the AV. .

2.6.3 Iodine Value (EN 14111)

Iodine value was ascertained using the Wijs method, to which iodine monochloride was added to the unsaturated fatty acid chains. The iodine absorbed was ascertained by titration against sodium thiosulfate as an indicator with starch.

2.6.4 Flash Point (ASTM D93)

Flash point was measured with a Pensky–Martens closed-cup test apparatus. It is an important factor in the transportation and safe storage of biodiesel.

2.6.5 Free Fatty Acid (FFA) Content

FFA content was indirectly measured by acid value which assists in determining the esterification effectiveness and the purity of the product. According to Abatyough et al. (2019). This assisted in determining the esterification effectiveness and product purity.

$$\textbf{\% FFA} = \frac{Acid\ Value}{1.99}$$

2.7 Data Interpretation and Quality Compliance

These values obtained through measurement for all the physicochemical parameters were also verified with standard limits mentioned in biodiesel standards. Samples meeting or even exceeding both standard limits were found to be fit for the use as biodiesel in compression ignition engines.

2.8 Yield Calculation

Biodiesel yield (%) was calculated using the following equation:

$$\textbf{Yield (\%)} = \frac{Weight\ of\ biodiesel\ produced}{Weight\ of\ oil\ used}\ x\ 100$$

3.1 Catalyst Performance Evaluation

The catalytic efficiency of heterogeneous zeolite-based catalysts was critically assessed by evaluating biodiesel yield under varying operational parameters and across multiple reaction cycles. Two catalysts were compared Sn-RH-Zeolite and K_2CO_3-CaO-Zeolite both synthesized from low-cost and sustainable precursors. This section outlines the performance metrics in terms of yield, influence of reaction conditions, and cycle-wise reusability trends.

3.1 Catalyst Performance Evaluation

Catalytic efficiency of heterogeneous zeolite-based catalysts was evaluated critically by contrasting biodiesel yield under different operating conditions and for multiple reaction cycles. The efficiency of two catalysts prepared from cost-effective and ecofriendly precursors Sn-RH-Zeolite and K_2CO_3-CaO-Zeolite was compared. The performance attributes in terms of yield, effect of reaction conditions, and cycle-wise reuse trend are highlighted in this section.

3.1.1 Sn-RH-Zeolite and K_2CO_3–CaO–Zeolite Yield Comparison

Biodiesel yield is a critical measure of catalyst efficiency. Under ideal conditions, both Sn-RH-Zeolite and K_2CO_3-CaO-Zeolite were active catalysts, with yields of more than 90%. For instance, Sn-RH-Zeolite yielded 93.6% using waste sunflower oil, and K_2CO_3-CaO-Zeolite yielded 93.2% using waste mustard oil. This difference in performance is reflective of catalyst compatibility with feedstock characteristics. Medium free fatty acid (FFA) and higher iodine value sunflower oil was favored by the twin acidity of Sn-RH-Zeolite, allowing for both esterification and transesterification. Highly basic K_2CO_3–CaO–Zeolite, by contrast, was compatible with low-FFA mustard oil but would perform less efficiently on more degraded oils due to the risk of soap formation. These results suggest that Sn-RH-Zeolite would be more suited to moderately degraded or unsaturated oils, while K_2CO_3–CaO–Zeolite would be more suited to cleaner, low-FFA oils.

3.1.2 Effect of Methanol-to-Oil Ratio, Catalyst Loading, and Reaction Time

Transesterification is an equilibrium-controlled reaction, and equilibrium towards methyl ester production can be attained by optimizing the important parameters. Three parameters were controlled in this work, i.e., methanol-to-oil mole ratio, catalyst loading, and reaction time. All reactions were conducted at a constant temperature of 65 °C.

Table:1 Comparison of Transesterification Parameters for Sn-RH-Zeolite and K_2CO_3–CaO–Zeolite Catalysts

Parameter	Sn-RH-Zeolite	K_2CO_3–CaO–Zeolite
Methanol-to-Oil Ratio	9:1	15:1
Rationale	Sufficient for dual-acid catalyst working with moderately impure oils	Excess methanol shifts equilibrium and compensates for FFA sensitivity in base-catalyzed reactions
Catalyst Dosage	3 wt.%	4 wt.%
Implication	Lower amount needed due to better dispersion and surface activity	Higher amount required to ensure adequate active site availability
Reaction Time	180 minutes	120 minutes
Reason	Slower reaction due to combined esterification and transesterification	Faster kinetics typical of basic catalysts

These results indicate that Sn-RH-Zeolite can work effectively at decreased catalyst loading and methanol feed, but at the cost of increased reaction time. Alternatively, the K_2CO_3-CaO-Zeolite provides quicker conversion but at the cost of strict feedstock conditions and increased methanol feed.

3.1.3 Catalyst Reusability and Yield Degradation over Cycles

Reusability of heterogeneous catalysts is an effective consideration for their economic and operational feasibility in the process of biodiesel manufacture. In the current study, Sn-RH-Zeolite and K_2CO_3-CaO-Zeolite were employed in four successive transesterification cycles under the same reaction conditions to assess long-term deactivation of catalytic performance. The catalysts were separated after each cycle, washed thoroughly with ethanol to desorb absorbed glycerol and excess oil, and dried at 100 °C for 4 hours before reuse.

Catalyst Reusability Summary

Sn-RH-Zeolite showed good reusability, and yield of biodiesel declined from 94.2% in Cycle 1 to 76.5% in Cycle 4, i.e., an 17.7% decline. This decline is mainly attributed to Sn species leaching and blockage of pores, but the catalyst also exhibited good activity due to its dual acid sites and structural stability.

K_2CO_3-CaO-Zeolite started at 92.6% yield in Cycle 1 and dropped to 72.9% in Cycle 4 a decline of 19.7%. Spurred degradation was the result of leaching of K and Ca species, reduced surface basicity, and soap formation, especially in the case of very slightly impure oils.

Overall, Sn-RH-Zeolite showed better reusability and stability and was therefore more suitable for treatment of variable-quality WCOs in repeated cycles.

To better show the relative trend in catalyst performance, the following table and the following explanation summarize the biodiesel yield in four cycles:

Cycle No.	SRZ	KCZ Yield (%)
Cycle 1	94.2	92.6
Cycle 2	89.7	87.1
Cycle 3	83.4	80.2
Cycle 4	76.5	72.9

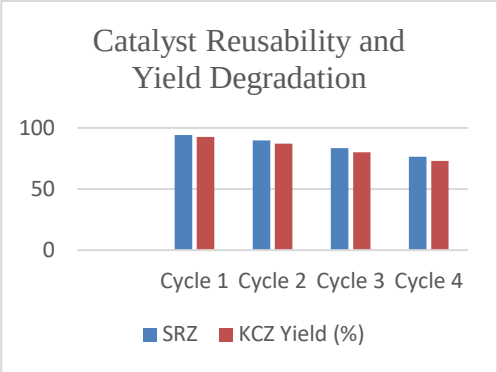

Table 2- Catalyst Reusability **Fig. 1 Graphical Representation**

3.2 Physicochemical Properties of Biodiesel

Physicochemical properties of WSO biodiesel and WMO biodiesel are shown in Table 3. These are of utmost significance in the determination of fuel properties within acceptable limits. Viscosity of the samples of the biodiesel was determined at 40 °C by a Redwood Viscometer according to ASTM D445. WSO biodiesel registered 4.3 mm^2/s viscosity, whereas WMO biodiesel registered 4.7 mm^2/s slightly higher viscosity. Both are within the acceptable range (1.9–6.0 mm^2/s) and are an indication of excellent diesel fuel application flow characteristics with no blending or additives. Acid value is directly related to the FFAs left behind, which corrode engine parts. According to ASTM D664, titration analysis showed acid value to be 0.017 mg KOH/g in the case of WSO biodiesel and 0.37 mg KOH/g in the case of WMO biodiesel. Both were below the 0.50 mg KOH/g standard limit, indicating that FFAs were successfully converted to methyl esters by the catalysts. Iodine value is an indication of the state of unsaturation in the biodiesel. Higher iodine values indicate higher unsaturation, which lowers oxidative stability. WSO biodiesel registered around 114 g I_2/100 g of iodine value, whereas WMO biodiesel registered around 107 g I_2/100 g of iodine value. Both were below the 120 g I_2/100 g limit of EN 14214, although WSO contained slightly higher unsaturation due to the inherent linoleic acid content. Flash point is a safety parameter of prime importance in storage and transportation. Pensky-Martens closed-cup tester readings as per ASTM D93 showed flash points at 170 °C for WSO biodiesel and 150 °C for WMO biodiesel. These are significantly higher than the ASTM specification of 93 °C and the EN specification of 101 °C, suggesting complete removal of residual methanol and safe storage. Free fatty acid (FFA) content, not explicitly discussed in ASTM or EN standards, was estimated from acid values (Abatyough et al., 2019). FFA content was found to be ~0.1% for WSO biodiesel and ~0.6% for WMO biodiesel. The higher FFA content in WMO could be due to extended frying cycles, which hydrolyze triglycerides to FFAs. This higher FFA content reduces the transesterification efficiency and calls for increased tolerance of the catalyst. Overall,

both the samples of biodiesel complied with international standards, with WSO biodiesel showing marginally superior quality parameters.

Table 3. Physicochemical Properties of Biodiesel Samples

Property	EN 14214 Standard	ASTM D6751 Standard	WSO Biodiesel	WMO Biodiesel
Viscosity (40 °C)	3.5–5.0 mm^2/s	1.9–6.0 mm^2/s	4.3 mm^2/s	4.7 mm^2/s
Acid Value	≤ 0.50 mg KOH/g	≤ 0.50 mg KOH/g	0.017 mg KOH/g	0.37 mg KOH/g
Iodine Value	≤ 120 g I_2/100 g	Not Specified	114 g I_2/100 g	107 g I_2/100 g
Flash Point	≥ 101 °C	≥ 93 °C	170 °C	150 °C
FFA Content (%)	Not Specified	Not Specified	~0.1%	~0.6%

3.2.6 Analysis of Variation

Variations in biodiesel qualities can be explained by the nature of the feedstock and the level of degradation that happens during frying. WSO, having lower FFA and improved oxidative stability, had slightly better acid and iodine values for the biodiesel. WMO, due to its possible degradation through cooking, had slightly higher acid and FFA values but within specifications. Such variation emphasizes the need to use the appropriate catalysts and pretreatment processes to handle varying qualities of waste oil.

3.3 FT-IR Analysis of WMO Biodiesel

FTIR spectrum of waste mustard oil (WMO) biodiesel was recorded from the wave number range of 400–4000 cm^{-1} to detect the various functional groups present in biodiesel sample. FTIR spectrum of WMO

biodiesel is shown in Fig.2, which shows the presence of methylene stretching vibrations at 2924.45 cm^{-1} that agrees with the presence of aliphatic CH_2 chains typical of FAME. The presence of a sharp peak within the range of 1737.92–1742.46 cm^{-1} shows carbonyl (C=O) group typical of ester linkages, and hence the successful transesterification of triglycerides to methyl esters. In addition, other bands at 2854.10 cm^{-1} and 1455.30 cm^{-1} show symmetric CH_2 stretching and bending vibrations, respectively. Moreover, some weak bands were noted between 700 and 500 cm^{-1} at 551.99 cm^{-1} and 472.25 cm^{-1}, which are typical of skeletal vibrations typical of long-chain hydrocarbons. The absence of a broad O–H peak at 3400 cm^{-1} indicates that excess H_2O and unreacted FFA were removed successfully. The observation is corroborative of low FFA content and greater purity of biodiesel product, as evidenced by the reported physicochemical values.

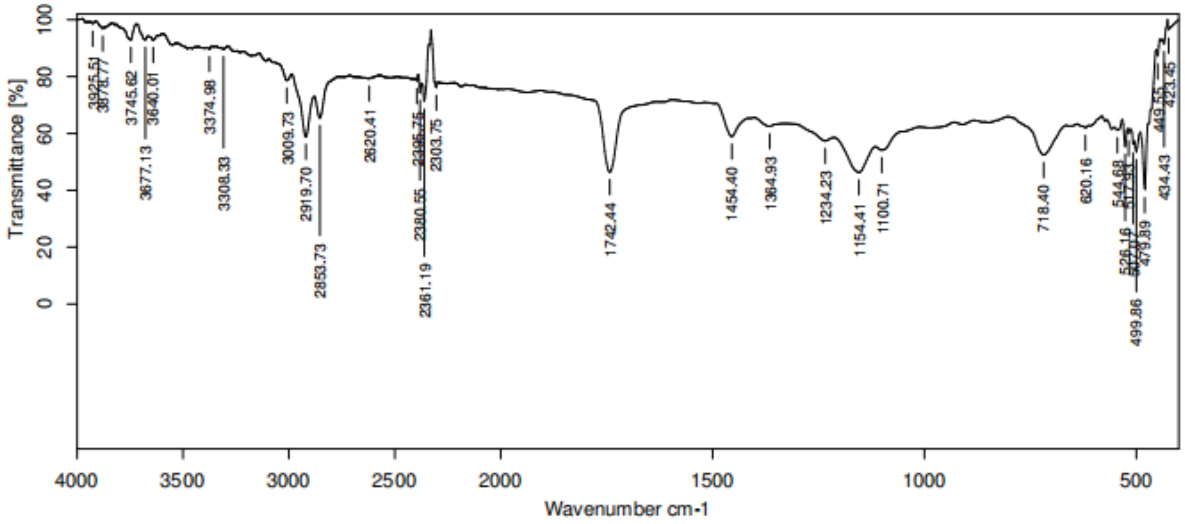

Fig. 2 FTIR of WMO

3.3 Catalyst Reusability and Stability

The reusability of heterogeneous catalysts is essential for cost-effective and sustainable biodiesel production. Both Sn-RH-Zeolite and K_2CO_3–CaO–Zeolite catalysts were evaluated over five reuse cycles to assess stability and performance.

3.3.1 Sn-RH-Zeolite

FTIR Analysis showed retention of characteristic peaks (–OH at ~3440 cm^{-1}, Si–O–Si at 1000–1100 cm^{-1}, Sn–O–Si at ~960 cm^{-1}). Slight reduction in hydroxyl bands was observed, with no signs of carbon deposition shown by fig. 3.

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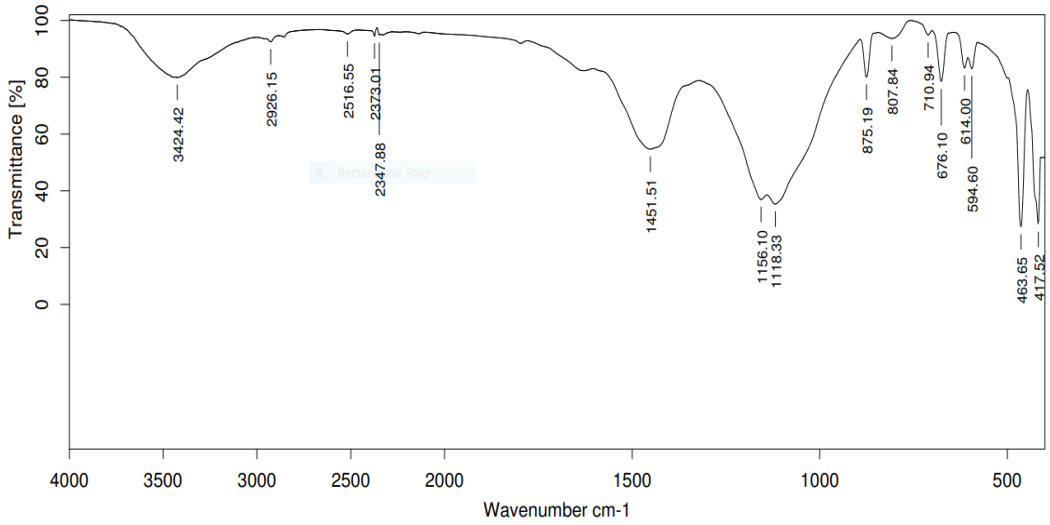

Fig.3- FTIR of SRH Catalyst

XRD Analysis confirmed that major diffraction peaks (2θ = 8.73°, 25.43°) remained unchanged, with minor peak broadening indicating slight crystallite degradation. No impurity phases like SnO_2 were detected.

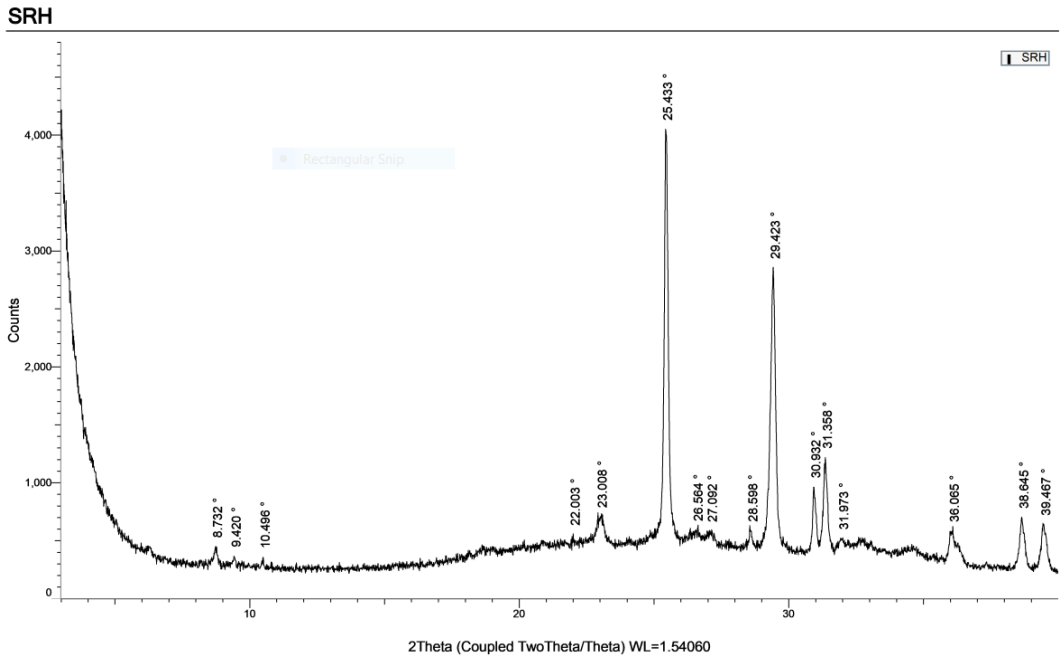

Fig.4-XRD of SRH Catalyst

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Yield Trend fell from 94.2% (Cycle 1) to 70.2.% (Cycle 5) primarily as a result of Sn leaching and pore blocking, but retained high catalytic activity.
Implication: Exhibited good reusability and structural stability, showing that it can be used with high-FFA waste oils and continuous use systems.

3.3.2 K_2CO_3–CaO–Zeolite (KCZ)

Decrease in Yield Performance over cycles:
Palm oil: 96% → 82.4% (Cycle 3)
Soybean oil: 76% → 59.3% (Cycle 5)
Groundnut oil: 86.4% → 72.5% (Cycle 3)

Reduction was associated with leaching of Ca^{2+} and K^+, surface fouling, and physical deterioration. FTIR Analysis showed recurring –OH peaks (~3440 cm^{-1}) with decreasing carbonate bands (1460, 875, 712 cm^{-1}), indicating partial loss of K_2CO_3.

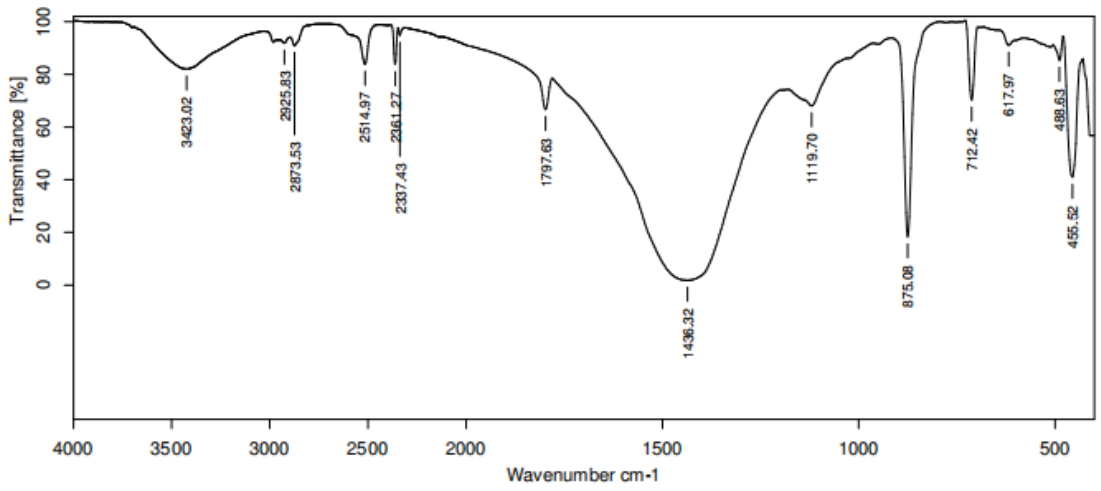

Fig.5-FTIR of KCZ Catalyst

XRD Patterns maintained major reflections (29.39°, 36.01°, 39.45°), although with decreased intensities (10–15%), indicating slow loss of crystallinity. Zeolite support was structurally stable (22°–28°).

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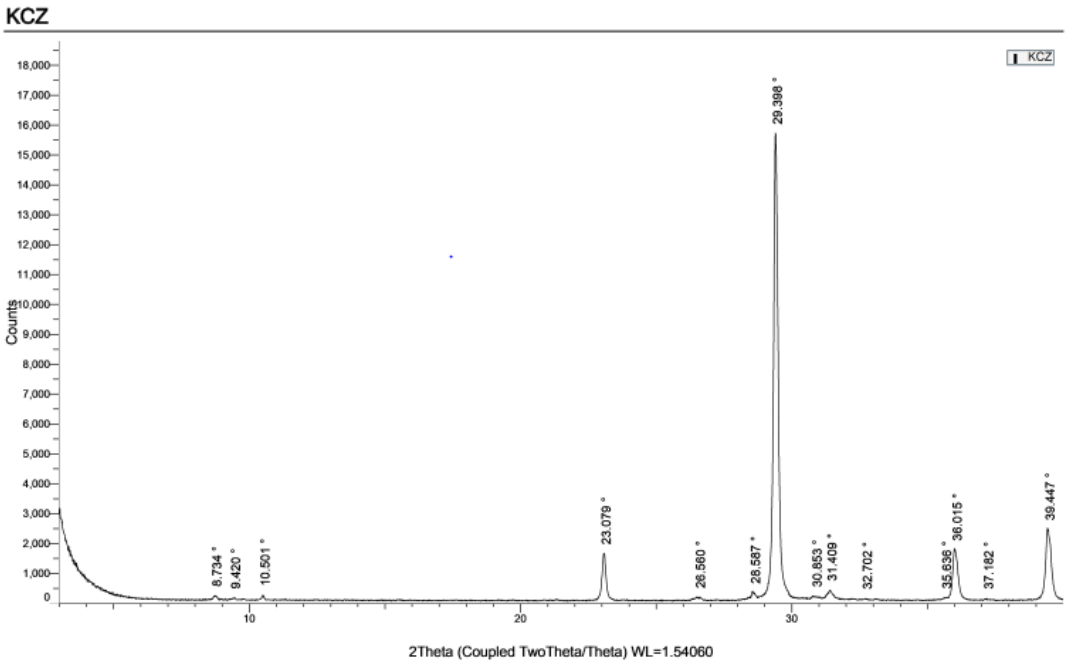

Fig. 6 - XRD of KCZ Catalyst

Conclusion and Future Scope

This research effectively proved the feasibility of two modified heterogeneous catalysts Sn-RH-Zeolite and K_2CO_3-CaO-Zeolite for the effective production of biodiesel from WCO. Both catalysts produced biodiesel yields of over 93% under the optimal conditions. Sn-RH-Zeolite was more resistant to FFAs and more reusable with structural stability established through FTIR and XRD. K_2CO_3-CaO-Zeolite exhibited higher performance loss on account of leaching and surface modification. The resulting biodiesel was in accordance internationally accepted biodiesel specifications for viscosity, acid value, iodine value, flash point, and FFA content, and it was suitable for diesel engine fuel. Variations in fuel quality reflected the nature and extent of degradation of the feedstock, highlighting the importance of proper pretreatment and catalyst selection. Future research could entail catalyst regeneration, process scale up, and investigation of varied feedstocks. Kinetic modelling, life cycle assessment, and glycerol valorization could further increase the environmental as well as economic sustainability of the process. Overall, these catalysts offer a sustainable route for biodiesel production and make a significant contribution to circular bio-economy strategies.

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Solar Soaring: Cochin International Airport's Sustainability Success

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Case Summary

Air transport interconnects today's world serving transportation of goods and passengers across the globe. The study's agenda is aviation sustainability with a detailed examination of Cochin International Airport's innovative solution to the energy crisis. Green airports are becoming increasingly important across India, driven by factors like growing traffic, the need to reduce carbon emissions, financial and sustainability requirements. In the country, airports are managed either by the 'Airports Authority of India' (AAI) or through 'Public-Private Partnerships' (PPP). This study focuses on aviation sustainability, with Cochin International Airport's innovative solution to the energy crisis. The effectiveness of solar-powered airport in reducing the carbon emission leads to a zero-emission, clean, and sustainable green airport confirmed through economic and environmental evaluations.

Background of the Case

Cochin International Airport Limited (CIAL) is the first airport in India constructed under 'Public-Private Partnership (PPP)' model in Nedumbassery, Kerala. It is the busiest airport in state and ranks fifth in India for international traffic. CIAL is globally first fully solar-powered airport with its 50 MWp solar plant generating 200,000 units of power daily. The airport serves over 25 airlines with connections to 31 international and 22 domestic destinations. It has earned several awards including United Nations' Champion of the Earth award.

Research Questions

The case of CIAL aims to resolve key issues:

1) Operational Efficiency: How can CIAL sustain high operational performance while integrating sustainable practices?
2) Traffic Management: What sustainable strategies can be implemented to manage the rising volume of air traffic?
3) Carbon Emissions: How effective are the current measures in reducing CO2 emissions, and what further improvements are possible?
4) Financial Viability: How can financial sustainability be ensured while investing in green initiatives?
5) Technological Innovation: What new technologies can be adopted to enhance sustainability efforts?

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6) Stakeholder Engagement: How can stakeholders be effectively enhancing sustainability goals?

Theory

Cochin Airport, the world's first airfield powered solely by solar energy, has made a significant mark in aviation history. Its daily power consumption has now reached 48,000 units (KWh). In March 2013, the airport, known for its commitment to sustainable development, entered the solar photovoltaic power station (PV) market with a 100-kilowatt peak (KWp) solar PV plant installed on the roof of the Arrival Terminal Block. Since its installation, this plant has helped reduce CO2 emissions by over 550 metric tons, supporting CIAL's endeavors to combat environmental degradation. With a mere 26% ownership by the State and Central Governments, it stands as India's premier international airfield.

Source:'https://swarajyamag.com/infrastructure/worlds-first-solar-powered-airport-at-cochin-is-indias-champion-of-sustainable-energy-report'

Basis of the Case: Phenomenon or Event

One of the most significant development drivers in the CIAL sustainability case is the growth of investments in sustainable energy, especially in solar power.

Thanks to good policies and decreasing prices, renewable energy investments are going very high in the year 2024 in Asia-pacific region. World Solar Investment report says 59% of the renewable energy investments are

made on solar and total number of investments in the energy sector crosses almost $3 trillion. It reflects the importance of sustainable approaches to the world's energy industry.

This event addresses many of the global challenges and goals towards sustainability. The event reduces the greenhouse gas emission thereby mitigating climate changes. It ensures energy security through diversity, catalyses economic growth through innovation, employment, economic development and triggers resource efficiency towards the efficient use of natural resources. In addition, the event supports all the global goals in response to UNSDG 7 ‘Affordable and clean energy’ as well as UNSDG 13 ‘Climate Action’.

Source: ‘Behind The Scenes At CIAL—the World's First Solar-powered Airport - Forbes India’

Options to Resolve the Dilemma

Strategies

The sustainability strategies include ‘Cochin International Airport’ as the world's first fully powered airport by solar energy, upgrading its water and waste management system, and incorporating energy efficiency technologies in its facility. The organization also preserves biodiversity and promotes eco-friendly transportation by providing charging facilities for electric vehicles. These efforts resonate well with the global agenda of sustainability, particularly on the UN's ‘SDG 7 (Affordable and Clean Energy)’ and ‘SDG 13 (Climate Action)’.

Pros:

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These are some of the benefits of Cochin International Airport Limited's (CIAL) sustainability efforts.

1.Reduction of carbon footprint through the utilisation of solar power and energy-efficient technology.

2.Conservation of energy and water in the long term, as renewable sources of energy and efficient utilisation of resources would result in maximum savings.

3.Gaining International Status as a Pace Setter in Sustainable Practice and to attract environment-conscious tourists and business.

4.Being align to international best practices and goals in sustainability in accordance with that of United Nations SDGs.

5.Encouragement of innovation and adoption of new or newest technology for sustainability

6.Benefits to community by creating employment opportunities and removing harmful manifestations from the environment.

Opportunities

1. Technological advancements: Innovative energy efficient technologies would help CIAL scale up their green efforts very considerably.
2. Government Support: Positive policies and state incentives toward a green environment bring about financial and regulatory benefits.
3. Collaborative Efforts: Building the strength of partnerships with stakeholders can lead to some shared resources and expertise accelerating the goal for sustainability.
4. World Recognition: A leader in green practices increases the reputation of CIAL at the world level, thereby inviting more business and partners.
5. Community Engagement: Community engagement in sustainability initiatives by the airport can gain support and cooperation, thus strengthening airport social license.

Challenges

1. Initial Investment: High Upfront Cost of Expanding Solar Capacity Also Associated with Adoption of New Technologies.
2. Regulatory Landscape: Navigating the complex dynamics of environment regulations.
3. Coordinating effectively: It is a very tough task to manage communication and collaboration among a group of stakeholders, ranging from diverse gender, ethnicity, age, and experience levels.
4. Operational Integration: The addition of new sustainable technologies without interference with existing operations.
5. Market Dynamics: Responsive and yielding to changes in the market as well as the marketplace's economic fluctuations, which could affect funding and investing in sustainable projects.

Conclusion

The example CIAL has set by becoming the world's first fully solar-powered airport in paving a benchmark way for renewable energy in the air transport industry is simply exemplary.

CIAL's vision about the global goals of sustainability-the United Nations ‘Sustainable Development Goals 7 (Affordable and Clean Energy) and 13 (Climate Action)’-suggest commitment to a greener future.

The very effective and innovative sustainability practices of CIAL have emerged as landmark models for a lot of other airports and beyond in pursuit of environmental and economic sustainability. Sustainable practices at CIAL highlight incredible potential for benefit generation when sustainability is allowed to permeate core strategies of operations.

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India and SDG 4: Measuring Educational Progress Through Indicators and Insights

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ABSTRACT

This study evaluates India's progress toward achieving Sustainable Development Goal 4 (SDG 4), which aims to ensure inclusive and equitable quality education and promote lifelong learning by 2030. Adopting a mixed-methods approach, it combines quantitative analysis of national and national data with qualitative insights from policy reviews and stakeholder perspectives. The findings indicate notable improvements in enrolment rates, infrastructure, and policy reforms—particularly through the Right to Education Act and the National Education Policy (NEP) 2020. However, significant challenges persist, including disparities in access, poor foundational learning outcomes, and limited inclusion of marginalized groups. These gaps hinder the realization of SDG 4 targets. The study offers targeted policy recommendations such as equity-based funding, inclusive pedagogy, teacher capacity building, and community engagement. By highlighting both achievements and persistent barriers, the research contributes valuable insights for policymakers and stakeholders striving to enhance educational equity and quality in India.

Keywords: *Sustainable Development Goals (SDGs), National Education Policy (NEP) 2020, Quality education, NITI Aayog, United Nations, 2015.*

1. Introduction:

Education is a fundamental driver of sustainable development, playing a transformative role in improving quality of life and addressing pressing global challenges. Sustainable Development Goal 4 (SDG 4) aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" by 2030 (UN Statistics Division). As a cornerstone of the global development agenda, SDG 4 emphasizes access to quality education for all individuals, regardless of background, thereby helping to the reduction of inequalities within the country and among the countries (Mariyam, 2022).

Special attention is given to marginalized groups, including children with communication disabilities in underserved communities, ensuring they receive tailored support to meet their specific needs—thus advancing social inclusion and overall well-being. Higher education institutions also play a crucial role in achieving SDG 4 by promoting equal access to tertiary education, fostering lifelong learning, and driving research and innovation for societal progress (Maia, 2021). Moreover, the integration of digital education technologies has

emerged as a strategic tool to support SDG 4 by enhancing learning outcomes, bridging gender gaps, and ensuring access to high-quality, inclusive educational content (Agung, 2023).

In India, the implementation of SDG 4 is coordinated by NITI Aayog, which has developed strategic frameworks, including the Three-Year Action Agenda (2017–18 to 2019–20), a 15-year vision, and a corresponding seven-year strategy, to align national agendas with global educational goals (NITI Aayog). Through these efforts, India is striving to create an inclusive, equitable, and quality-driven education system that supports sustainable development at all levels.

2. Research objectives

1. To assess India's progress on key SDG 4 indicators between 2015 and 2025 using national and international data sources.
2. To examine the major challenges and bottlenecks hindering the achievement of SDG 4 in India.
3. To suggest policy measures that can enhance the pace of achieving inclusive and equitable quality education aligning with SDG 4.

3. Research problem

The research problem is to assess India's progress, challenges, and opportunities in achieving SDG 4.

4. Research Designs/Methodology

The study adopts a mixed-methods research design, integrating both descriptive and analytical approaches. Quantitative analysis is employed to examine trends and progress in key SDG 4 indicators in India from 2015 to 2025, drawing on secondary data from national and international sources. Qualitative analysis is employed to assess relevant policy measures and explore the challenges hindering progress. This approach enables a comprehensive understanding of India's achievements, existing gaps, and future directions in advancing inclusive and equitable quality education. The structure of the paper is as follows: Section 5 presents the literature review; Section 6 provides the discussion, which includes an overview of SDG 4 targets and indicators, an investigation of India's progress based on key indicators, identification of key challenges to achieving SDG 4 by 2030, and an examination of policy interventions; and Section 7 offers the conclusion.

5. Literature Review

The global discourse on Sustainable Development Goal 4 (SDG 4), which seeks to ensure inclusive, equitable, and quality education for all by 2030, has highlighted both achievements and persistent challenges. While there has been progress in expanding access to education globally, deep-rooted disparities continue to affect marginalized and socioeconomically disadvantaged groups (Wulff, 2020; Singh, 2024). The COVID-19 pandemic further exacerbated these inequalities by disrupting learning and widening the digital divide. Moreover, despite rising enrolment rates, learning outcomes remain suboptimal, with many students lacking basic literacy and numeracy skills (Singh, 2024). Methodological issues in data collection across some countries also hinder accurate assessment of progress, complicating global monitoring efforts (Babović et al., 2024). These concerns underline the urgency for targeted interventions, enhanced data systems, and inclusive policy reforms in the global pursuit of SDG 4.

A growing body of literature examines India's progress and challenges in achieving Sustainable development goal 4 (SDG 4), which seeks to ensure inclusive and equitable quality education for all. Despite notable achievements—such as increased primary school enrolment and improvements in female literacy (Singh, 2024)—several persistent issues hinder progress. These include poor learning outcomes, inadequate foundational literacy and numeracy skills, and widening educational inequalities, particularly exacerbated by the COVID-19 pandemic. Socioeconomic disparities, teacher shortages, insufficient training, and weak school infrastructure continue to marginalize vulnerable communities (Singh, 2024; Satapathy et al., n.d.; Mahananda, 2024).

Studies emphasize that structural and systemic barriers remain embedded in India's educational framework. Satapathy et al. (n.d.) and Mahananda (2024) advocate for curriculum modernization, stronger digital integration, and enhanced teacher preparation, particularly in rural areas where disparities in infrastructure and learning resources are most pronounced. Jena (2024) highlights deficiencies in teacher education programs, including limited internships and outdated pedagogical approaches that do not align with contemporary educational needs. Similarly, Chand (2024) calls for targeted strategies to bridge urban–rural gaps and to develop more inclusive, quality-focused, and responsive educational systems.

India's legislative efforts, most notably the **Right to Education Act (2009)**—enacted under the 86th Constitutional Amendment—sought to guarantee free and compulsory education for all children aged six to fourteen. This act institutionalized education as a fundamental right (Article 21A) and reflected the nation's commitment to democratic ideals, equity, and social welfare (Dubey, 2010; Saini, 2016; Garg et al., 2022). It explicitly prohibited expelling or holding back children until the completion of elementary education, aiming to reduce economic barriers to schooling (Dem, 2019; Yadav, 2012). However, implementation has been constrained by entrenched socio-economic inequalities and discriminatory cultural practices (Grewal & Singh, 2011; Choudhury et al., 2023).

The **National Education Policy (NEP) 2020** aims to address these systemic shortcomings by envisioning a holistic transformation of the education sector. It emphasizes multidisciplinary learning, digital inclusion, teacher development, and equity-driven reforms, with the goal of fostering skilled, socially responsible citizens while preserving India's cultural heritage (Rangarajan et al., 2023; Beerannavar & Pancrasius, 2024).

While the existing literature offers valuable insights into global and national efforts to achieve SDG 4, a critical need remains for empirical analysis that aligns directly with the official indicators and targets outlined by the United Nations. This research attempts to fill that gap by evaluating India's performance using selected core indicators that reflect access, quality, equity, and infrastructure in education. By drawing on national data sources such as UDISE+, ASER, and the SDG India Index, this study aims to offer a comprehensive, indicator-based assessment of India's progress from 2015 to 2025, highlighting key achievements, regional disparities, and policy challenges.

6. Discussions

6.1. Understanding SDG 4: Targets and Indicators

Goal Statement:
Sustainable Development Goal 4 (SDG 4) aims to *"ensure inclusive and equitable quality education and promote lifelong learning opportunities for all."* (United Nations, 2015). It reflects the recognition that

education is a fundamental driver of sustainable development, enabling social, economic, and environmental progress. The goal seeks to guarante that all children, youth, and adults—irrespective of gender, socioeconomic status, or geographical location—have access to quality education at all levels. Its focus extends beyond primary and secondary schooling to include early childhood care, technical and vocational training, higher education, adult literacy, and lifelong learning opportunities. It also emphasizes the elimination of disparities, promotion of equity, and improvement of educational infrastructure to support effective learning environments.

Key Targets of SDG 4

- **4.1** Ensure that by 2030, all girls and boys complete free, equitable, and quality primary and secondary education leading to relevant and effective learning outcomes (United Nations, 2015).
- **4.2** By 2030, Ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are prepared for primary education (United Nations, 2015).
- **4.3** By 2030, ensure equal access for all women and men to affordable and quality technical, vocational, and tertiary education, including university (United Nations, 2015).
- **4.4** By 2030, substantially increase the number of youth and adults who possess relevant skills—including technical and vocational skills—for employment, decent work, and entrepreneurship (United Nations, 2015)
- **4.5** By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for vulnerable groups, including persons with disabilities, indigenous peoples, and children in vulnerable situations (United Nations, 2015).
- **4.6** By 2030, Ensure that all the youth and a major proportion of adults, both men and women, achieve literacy and numeracy (United Nations, 2015)
- **4.7** By 2030, Make sure that all learners receive the knowledge and skills needed to promote sustainable development, including, among others, education for sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and its contribution to sustainable development (United Nations, 2015).
- **4.a** Build and improve education facilities that are child-, disability-, and gender-sensitive, and provide safe, secure, inclusive, and more effective learning environments for all (United Nations, 2015).
- **4.b** By 2020, substantially increase globally the number of scholarships available to developing countries—especially least developed countries (LDCs), small island developing states (SIDS), and African countries—for enrolment in higher education, including vocational training and programs in information and communications technology, technical, engineering, and scientific fields, in both developed and other developing countries (United Nations, 2015).
- **4.c** By 2030, substantially enhance the supply of qualified teachers, with the aid of international collaboration and making provision for teacher training in developing countries, particularly in LDCs and SIDS (United Nations, 2015).

6.2. India’s Progress: Achievements Based on Key Indicators

To measure India's progress in SDG- 4, the current study selected few indicators and analyse progress from **2015 to 2024**.

1. Gross Enrolment Ratio (GER): Since 2015, India's Gross enrolment ratio (GER) at the primary level (Grades 1–5) has remained consistently near 100%, reflecting near-universal access to elementary education. Enrolment at the upper primary level (Grades 6–8) has shown steady improvement, rising from around 92% in 2015 to about 97% by 2023, indicating better retention and transition from lower grades. At the secondary level (Grades 9–10), progress has been slower but positive, with GER increasing from approximately 78% in 2015 to around 82% in 2023, highlighting continued efforts to expand participation at higher stages of schooling. Despite these gains, bridging the remaining gaps at the secondary level and improving learning quality remain critical for meeting SDG 4.1 targets.

2. Learning Outcomes (Indicator 4.1.1): Between 2016 and 2024, India's foundational learning indicators improved but remain below desired proficiency levels. For Grade 3, the proportion of students able to read a Grade 2-level text increased from 7% to 28%, and those able to perform basic subtraction rose from 8% to 32%. At Grade 5, reading proficiency improved from 24% to 51%, while division skills increased from 10% to 32%. Despite these gains, a substantial share of students continues to fall short of minimum benchmarks, underscoring the need for sustained and targeted interventions. Similar trends are evident at the secondary level, where universal school access has not yet translated into universal acquisition of core competencies—an essential prerequisite for achieving SDG 4.1.

3. Completion Rates (Indicator 4.1.2): India's **completion rates (Indicator 4.1.2)** show strong performance at the **primary level**, where rates have consistently remained above **90%**, supported by very low dropout levels (~1–1.5%) and a retention rate of around **95%**, indicating near-universal completion. At the **upper primary stage**, completion has improved gradually, with moderate dropout rates declining over the years as retention strengthened. In contrast, the **secondary level** continues to face challenges: completion rates increased only modestly from about **55% in 2015 to roughly 60–62% by 2023**, and dropout rates remain higher (~12–16%), though retention improved to approximately **64.7% in 2021–22**. While progress is evident, particularly in early grades, reducing secondary-level dropouts and ensuring smoother transitions remain critical to achieving SDG 4.1 targets.

4. Gender Parity: The Gender Parity Index (GPI) data revealed that India already surpassed 1.00 post 2020, suggesting better female enrolment at the **primary level** (GPI ≈ 1.03 in both 2021–22 and 2023–24), indicating slightly higher enrolment for girls than boys. At the **secondary level** (Grades 9–10), the GPI was **1.0** in 2021–22, reflecting balanced enrolment between genders. By **higher secondary (Grades 11–12)** in 2023–24, the GPI increased to **1.07**, suggesting that female enrolment outpaced male enrolment at this stage. Rural versus urban GPI for GER is not directly reported; literacy rate gaps are often used as a proxy to infer such trends.

5. School infrastructure: Between 2015 and 2023, India has made significant progress in school infrastructure, a core focus of SDG 4. Basic amenities have reached near-universal coverage, with electricity access increasing from 70.2% to 92.8% and drinking water availability from 88.3% to 95.6%. Functional toilets, including separate facilities for girls, expanded from 60% to 84.5% and exceeded 98% by 2023–24, while handwashing facilities improved from 55% to 80.1%. These advancements, supported by initiatives such as the Samagra Shiksha Abhiyan, have enhanced the physical learning environment. However, digital infrastructure remains a critical gap: the proportion of schools equipped with computers rose from 47.5% to 57.2% between 2021–22 and 2023–24, and those with internet connectivity increased from 33.9% to 53.9%.

Despite this progress, substantial disparities persist across rural and urban areas and between government and private schools, highlighting the need for focused policies to strengthen ICT infrastructure and bridge the digital divide in order to fully meet SDG 4's quality and equity goals.

6. Teacher availability: In India, the availability of trained teachers—a key requirement under SDG 4 (Indicator 4.c.1)—has improved but varies across educational levels. At the primary level, approximately 85–87% of teachers were formally trained by 2023, while the upper primary level recorded around 80–82%. At the secondary stage, the proportion is lower, averaging 75–78%, and at the higher secondary level, trained teacher availability falls further to about 70–72%. Although these figures reflect progress compared to 2015, achieving universal teacher training (100%) by 2030 remains a challenge, particularly at secondary and higher secondary levels.

7. Pupil-Teacher Ratio (PTR): Since 2015, India's Pupil-Teacher Ratio (PTR) has steadily improved across all levels of school education, reflecting progress toward SDG 4 quality targets. At the **primary level**, PTR declined from about **28:1 in 2018–19 to nearly 26:1 by 2021–22**, while at the **upper primary level** it improved from around **19:1 to 19.4:1** in the same period. The **secondary level** achieved an even better ratio, reaching approximately **17:1**, and the **higher secondary level** stands at about **27:1**. These figures are well below the SDG benchmark of **30:1**, suggesting better teacher availability and the potential for more focused student engagement. However, state-level disparities and uneven rural–urban teacher distribution remain critical areas requiring policy attention.

To sum up, India's overall SDG performance has improved in recent years, with its composite score rising from 66 in 2020–21 to 71 in 2023–24, according to the **NITI Aayog SDG India Index 2023–24**. Among all goals, **SDG 4 (Quality Education)** has shown particularly rapid progress, with its score increasing from 63 in 2018 to 89, making it one of the fastest-improving areas. This advancement reflects notable gains in school enrolment, availability of necessary key infrastructure such as electricity, drinking water, and functional toilets, as well as increased accessibility to educational facilities. States like Kerala and Delhi have emerged as top performers, demonstrating stronger achievements in meeting the benchmarks for quality education.

Despite these positive trends, the **UNESCO Global Education Monitoring (GEM) Report** highlights a persistent and critical gap: while access to education has expanded significantly, learning outcomes have not kept pace. A substantial proportion of students, particularly at the primary and upper-primary levels, still lack foundational literacy and numeracy skills. This indicates that although policy initiatives and investments have effectively increased coverage and infrastructure, ensuring that children acquire essential competencies remains a major challenge. Bridging this gap between access and actual learning will be essential for India to fully achieve the objectives of **SDG 4 by 2030**.

6.3. Challenges Key Challenges to Achieving SDG 4 by 2030 (300–400 words)

India faces several significant challenges in achieving Sustainable Development Goal 4 (SDG 4), which seeks to ensure inclusive and equitable quality education for all. Although notable progress has been made in expanding enrolment and implementing initiatives namely, the Right to Education Act, Samagra Shiksha Abhiyan, and Beti Bachao Beti Padhao, persistent gaps continue to undermine both the quality and accessibility of education. These challenges span disparities in learning outcomes, infrastructural inadequacies, teacher shortages, and socio-economic barriers, all of which collectively impede India's ability to realize the full objectives of SDG 4.

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1. Socioeconomic Disparities

Socioeconomic inequalities remain one of the most formidable obstacles to equitable education in India. Children from low-income households, Scheduled Castes (SC), Scheduled Tribes (ST), and rural populations continue to face systemic barriers that hinder their access to quality education. According to Singh (2024), these marginalized groups often attend under-resourced schools, face financial constraints that limit school attendance, and encounter discrimination within educational settings. The **urban–rural divide** exacerbates these disparities significantly. In rural areas, not only are schools often sparsely distributed, but they also lack the basic educational infrastructure such as libraries, laboratories, and digital tools. Upreti and Malhotra (n.d.) highlight that rural students are further disadvantaged by limited access to skilled teachers and academic support services, which restricts their ability to compete with their urban counterparts. These structural inequalities perpetuate cycles of poverty and social exclusion, thereby undermining the inclusiveness and equity principles of SDG 4.

2. Infrastructure and Resource Constraints

Infrastructural and material shortages are widespread in India's public school system and pose a significant challenge to improving educational quality. As noted by Pandey (2019), many government schools operate in substandard buildings, with overcrowded classrooms, broken furniture, and insufficient access to clean water and functional sanitation facilities—especially for girls. Such conditions not only compromise the safety and hygiene of the learning environment but also contribute to high dropout rates. Furthermore, Singh (2024) emphasizes the chronic shortage of **qualified and adequately trained teachers**, particularly in rural and tribal areas. Many instructors lack formal pedagogical training or subject-matter expertise, which impairs the quality of instruction. Teacher absenteeism and poor student–teacher ratios also persist as problems. The lack of teaching-learning materials, including textbooks and digital resources, further restricts students' ability to learn effectively, particularly in remote and underserved regions. These systemic deficiencies create an environment where education delivery is inconsistent and often ineffective.

3. Challenges in Promoting Inclusive Education

Despite the enactment of policy frameworks such as the *Rights of Persons with Disabilities Act (2016)* and various inclusive education programs under *Samagra Shiksha*, children with disabilities continue to face significant hurdles in accessing equitable and quality education in India. The "Sustainable Development Goal 4" progress report (2022) indicates that most schools are still ill-equipped to accommodate students with diverse physical, cognitive, or sensory needs. There is lack of trained special educators, inaccessible infrastructure (e.g., ramps, assistive technologies), and adapted curricula. Additionally, the mainstream curriculum often fails to address varied learning styles and needs, which alienates not only children with disabilities but also those with learning difficulties or language barriers. Singh (2024) argues that the prevailing approach remains more integrative than truly inclusive—meaning children require individual learning needs are placed in regular classrooms without adequate support or curricular modifications. This highlights the urgent need for a **comprehensive policy overhaul**, enhanced teacher training, and a rethinking of curriculum design to ensure all learners are meaningfully included and supported.

While these issues are substantial, they also present opportunities for reform and innovation. By adopting targeted policies, strengthening institutional capacity, and fostering active community engagement, India can address these systemic gaps and accelerate progress toward the effective realization of SDG 4.

6.4. Policy Interventions

Table: Policy Interventions Addressing Key Education Challenges in India (Aligned with SDG 4 Targets)

Key Challenges	Targeted Policy Interventions	Relevant SDG 4 Targets
1. Socioeconomic Disparities	- Implement equity-based funding mechanisms for marginalized regions (rural, tribal, and urban slums). - Provide conditional cash transfers, free uniforms, and mid-day meals to socio-economically disadvantaged children. - Introduce bridge and remedial education programs. - Design and implement special initiatives to help children with disabilities and those from disadvantaged backgrounds, ensuring equitable access to quality education (Pandey, 2019; "Sustainable Development Goal 4", 2022).	**4.1**: Ensure inclusive and quality learning for everyone. **4.5**: Eliminate gender disparities and ensure equal access
2. Infrastructure & Resource Constraints	- Conduct a national audit and implement a time-bound modernization plan for upgrading school infrastructure, especially in rural and marginalized regions -Promote Public-Private Partnerships (PPPs) to provide ICT tools, smart classrooms, and digital learning platforms - Strengthen teacher recruitment, particularly in underserved areas, through rural incentives - Mandate ongoing professional development through platforms like DIKSHA and NISHTHA	**4.a**: Build and enhance education facilities **4.c**: Increase supply of qualified teachers

	- Prioritize investments in basic school facilities and learning resources to ensure a conducive and inclusive learning environment - Expand the pool of qualified teachers and enhance pedagogical quality through regular in-service training (Pandey, 2019)	
3. Inclusive Education Gaps	- Integrate inclusive education principles into pre-service and in-service teacher training programs - Recruit specialized staff including special educators, counsellors, and social workers to support diverse learner needs - Provide assistive learning materials and inclusive infrastructure through grants under *Samagra Shiksha* - Develop inclusive curricula and pedagogical approaches to accommodate varied learning needs - Promote lifelong learning through flexible and community-based education models to bridge access gaps (Mani, 2022)	**4.5**: Eliminate disparities for persons with disabilities. **4.a**: Safe and inclusive learning environments. **4.c:** Train teachers in inclusive education practices.
4. Community & Stakeholder Engagement	- Strengthen School Management Committees (SMCs) through capacity building, funding, and active participation from local communities - Conduct awareness campaigns to promote girl child education and increase parental involvement in school affairs - Establish digital learning hubs and deploy mobile learning vans in remote areas - Leverage digital platforms and AI-based tools to enhance teaching quality and offer personalized learning, especially for out-of-	**4.1**: Ensure effective learning for all **4.5**: Promote participation of marginalized communities **4.a**: Enhance local involvement

	school children and dropouts (Mani, 2022)	

Source: Author's Interpretation

7. Conclusion

India's journey toward achieving Sustainable Development Goal 4 has been marked by significant progress in expanding school access, improving infrastructure, and implementing landmark policy frameworks namely the National Education Policy 2020 and the Right to Education Act, etc. However, persistent challenges—particularly in learning outcomes, inclusivity, and equity—underscore the need for a comprehensive policy shift from access to quality. While targeted interventions and flagship programs have laid a strong foundation, bridging systemic gaps such as socioeconomic disparities, regional imbalances, and institutional inefficiencies remains imperative. Achieving SDG 4 by 2030 will require a sustained focus on educational quality, skill development, teacher capacity building, and robust monitoring frameworks, along with stronger stakeholder collaboration. Only by aligning quantitative expansion with qualitative transformation can India ensure that no learner is left behind in its pursuit of inclusive, equitable, and effective education for all.

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"Micro-Level Impact of SDG-Oriented Policies on Livelihood and Poverty: A Primary Study in Mumbai, Maharashtra"

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ABSTRACT

The Sustainable Development Goals (SDGs), adopted by the United Nations in 2015, set a global agenda to eliminate poverty, reduce inequality, and ensure inclusive development by 2030. Among them, SDG 1: No Poverty is especially critical for India, where a significant portion of the population still lives under challenging socio-economic conditions. This study aims to evaluate the effectiveness of India's poverty alleviation policies, especially in Maharashtra, with a focus on urban regions like Mumbai. Through primary data collection involving surveys and interviews, this research assesses how well schemes such as MGNREGA, PMAY, and Jan Dhan Yojana align with SDG objectives and impact the lives of economically weaker sections. The study seeks to identify gaps in implementation and suggest more localized, need-based strategies for poverty reduction.

Keywords: SDGs, Poverty, MGNEREGA

1. INTRODUCTION

India's journey toward becoming an inclusive and sustainable economy has been closely linked to its efforts to reduce poverty. While economic growth has lifted millions out of poverty, inequality remains a persistent challenge. The introduction of the Sustainable Development Goals (SDGs) provided a global framework to address these issues, with **SDG 1 (No Poverty)** at the core. As a nation committed to the SDG framework, India has launched several targeted poverty alleviation programs. However, their impact varies regionally due to economic, social, and administrative factors. Maharashtra, being one of the most industrialized and urbanized states, presents a unique case. This research focuses on **Mumbai**, where poverty and development coexist, to understand how national and state-level policies are contributing to SDG outcomes and improving the lives of the urban poor.

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2. REVIEW OF LITERATURE

A systematic review of literature provides an academic foundation for understanding the current status, challenges, and policy effectiveness of poverty alleviation initiatives in India. This section synthesizes findings from past research, reports, and scholarly work on the theme of poverty reduction, Sustainable Development Goals (particularly SDG 1: No Poverty), and government welfare schemes in the Indian context particularly focusing on urban areas like Mumbai.

1. The United Nations (2015) established **SDG 1: No Poverty** to end poverty in all forms everywhere by 2030. The SDGs emphasize inclusive development, social protection systems, equal access to economic resources, and building resilience among the poor. According to the **UNDP (2020)**, the success of SDG 1 depends largely on localized and need-based implementation of policies, particularly in densely populated urban settings like India.
2. Urban poverty in India presents a unique challenge, distinct from rural poverty due to overcrowding, informal employment, and housing shortages. **Kundu (2012)** argued that urban poverty is often underestimated due to exclusion errors in official poverty estimates. **Bhan (2016)** emphasized the need for spatial planning and inclusive housing strategies in slum-dominated cities like Mumbai to address urban poverty holistically.
3. **Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA):**
   While primarily rural-focused, studies such as by **Jha et al. (2019)** note spillover benefits in peri-urban areas, especially in stabilizing seasonal migration. However, in urban regions, the absence of an urban counterpart limits its effectiveness.
4. **Pradhan Mantri Awas Yojana (PMAY - Urban):** According to **MoHUA (2022)**, PMAY-Urban has made progress in approving affordable housing, but **Roy (2021)** notes that implementation has been delayed due to issues of land availability, legal tenure, and procedural complexity, especially in slums of Mumbai.
5. **Pradhan Mantri Jan Dhan Yojana (PMJDY):** As reported by **RBI (2021)**, Jan Dhan accounts have enhanced financial inclusion, especially for women and low-income families. However, **D'Souza**

(2020) points out that access alone does not ensure usage unless accompanied by financial literacy and linkage to credit and insurance.

6. **Patel et al. (2015)** examined urban housing insecurity and observed that most urban poverty persists due to inadequate housing policies. In Mumbai, with over 40% of the population living in slums, access to legal housing and clean infrastructure remains limited. Our findings show that **only 23% of beneficiaries received housing support**, underscoring this literature gap in real-world outcomes.

3. OBJECTIVES OF THE STUDY

1. To examine the role of Indian government policies in addressing poverty under the SDG framework.
2. To assess the level of awareness and access to poverty-alleviation schemes in Mumbai, Maharashtra.
3. To study the impact of these schemes on employment stability, housing, and income among poor and low-income groups.
4. To evaluate the challenges faced by beneficiaries in availing these schemes.
5. To suggest improvements and policy recommendations for better SDG alignment.

4. HYPOTHESIS OF STUDY:

- **H1:**
  There is a significant positive impact of Indian government poverty-alleviation policies on the livelihood of urban poor in Mumbai under the SDG framework.
- **H2:**
  Awareness and accessibility of poverty-alleviation schemes among low-income groups in Mumbai are significantly low.
- **H3:**
  Government welfare schemes have contributed to improved employment stability, housing conditions, and income levels among the beneficiaries.
- **H4:**

Beneficiaries face significant administrative and procedural challenges in availing the benefits of poverty-alleviation schemes.

- **H5:**
  Policy improvements and better local implementation strategies can significantly enhance the impact of SDG-aligned poverty-reduction efforts in Maharashtra.

Research Gap Identified

While extensive research exists on policy frameworks and scheme design, fewer studies assess the on-ground implementation and actual beneficiary experience in urban Maharashtra. This study fills the gap by focusing on Mumbai a city with both extensive poverty and concentrated government intervention and assessing how well these policies align with SDG 1 objectives in practice.

5. DATA ANALYSIS AND INTERPRETATION

This section presents the analysis of primary data collected from 200 respondents residing in low-income and slum areas of Mumbai, Maharashtra. The data was collected through structured questionnaires focusing on awareness, access, and impact of government poverty-alleviation schemes aligned with Sustainable Development Goal 1 (No Poverty).

Research Tools

To ensure the collection of rich and relevant data aligned with the study's objectives, a combination of quantitative and qualitative research tools was employed:

1. Structured Questionnaire

- A structured questionnaire was designed to gather **quantitative data** from the selected respondents belonging to economically weaker sections of urban Mumbai.
- The questionnaire comprised **both closed-ended and open-ended questions**.
  - **Closed-ended questions** helped in obtaining standardized responses suitable for statistical analysis (e.g., “Have you availed benefits under PMAY?” with Yes/No options).

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- **Open-ended questions** allowed respondents to freely express their experiences, opinions, and suggestions (e.g., "What challenges do you face in accessing government schemes?").

- The questionnaire was divided into multiple sections covering:
  - Demographic details (age, gender, education, income, occupation)
  - Awareness and accessibility of poverty alleviation schemes (MGNREGA, PMAY, Jan Dhan Yojana)
  - Impact on livelihood, housing, income stability, and quality of life
  - Satisfaction level and suggestions for improvement

- To ensure inclusivity, the questionnaire was made available in **English**, **Hindi**, and **Marathi**.

2. Interview Schedules

- A semi-structured interview guide was used for **key informant interviews** with:
  - Local government officers involved in scheme implementation
  - Representatives of NGOs working on poverty alleviation in urban areas
  - Community leaders or activists working at the grassroots level

- These interviews provided **contextual insights** on administrative processes, challenges in last-mile delivery, coordination between agencies, and feedback from beneficiaries.

- Interview schedules were flexible enough to allow in-depth discussions and follow-up questions based on the respondents' answers.

3. Focus Group Discussions (FGDs)

- In addition to individual responses, **FGDs were conducted with small groups (6–8 participants)** from the same locality or social group to understand **shared experiences and collective challenges**.

- FGDs were particularly useful for understanding perceptions of scheme effectiveness, community awareness, and social factors influencing access to benefits.

Quantitative Data Analysis

- Responses from structured questionnaires were coded and entered into statistical software (such as MS Excel or SPSS) for analysis.

- The following techniques were employed:

  Descriptive statistics such as mean, median, frequency, and percentages were used to summarize and describe the basic characteristics of the dataset. For example:

  - Percentage of respondents aware of PMAY
  - Average household income before and after scheme participation

- **Cross-tabulation** was used to examine relationships between two variables. For instance:
  - Cross-tabulating income levels with types of schemes availed
  - Gender-wise analysis of access to Jan Dhan Yojana benefits
  - Charts, bar graphs, and pie diagrams were used for data visualization to make the findings more interpretable.

2. Qualitative Data Analysis

- Responses from open-ended questions, interviews, and FGDs were analyzed using thematic analysis:
  - First, transcripts were read multiple times to become familiar with the data.
  - Key themes and patterns (e.g., "lack of awareness," "bureaucratic delay," "documentation challenges") were identified.
  - Verbatim quotes were extracted to highlight real-life experiences and voices of the urban poor.
- This method allowed for an in-depth understanding of not only what issues exist, but also why and how they occur, adding richness to the quantitative results.

6. SUMMARY INTERPRETATION

1. Awareness of Government Schemes

Awareness of Schemes	Number of Respondents	Percentage (%)
Yes	157	78.5%
No	43	21.5%

Interpretation:
A significant majority of respondents (78.5%) were aware of government schemes related to poverty alleviation. This indicates that awareness campaigns and communication efforts have reached many low-income communities in Mumbai. However, 21.5% still lack awareness, showing the need for deeper penetration into remote or less-informed areas.

2. Application for Schemes

Scheme Application Status	Number	Percentage
Applied	113	56.5%
Not Applied	87	43.5%

Interpretation:
While more than half (56.5%) of the respondents applied for government schemes, a considerable portion (43.5%) did not. This gap may stem from challenges like lack of documents, information, or trust in the system. It reveals a need to improve support for application processes at the community level.

3. Benefits Received from Schemes

Benefit Received	Number	Percentage
Fully Benefited	46	23.0%
Partially Benefited	52	26.0%
No Benefit Received	102	51.0%

Interpretation:
Only 23% of respondents received full benefits from the schemes, while 26% got partial benefits. A troubling 51% received no benefit despite many applying. This reflects systemic bottlenecks, eligibility barriers, or corruption issues, which must be addressed to ensure SDG implementation is effective and inclusive.

4. Impact on Income and Employment

Indicator	Percentage
Income Improved	14.5%
Employment Stable	12.0%

Interpretation:
The impact of schemes on actual economic upliftment appears weak. Just 14.5% experienced an increase in income, and only 12% saw employment stability. This suggests that while schemes may provide temporary relief, they are not leading to long-term economic stability for a majority of beneficiaries.

5. Housing Support Received

Housing Support Status	Percentage
Received	23.0%
Not Received/In Process	77.0%

Interpretation:
Only 23% of the respondents received support from housing schemes like **PMAY**, while 77% did not. This highlights challenges in housing scheme eligibility, land/legal documentation, or poor coverage. Considering Mumbai's high housing costs and slum population, this is a critical gap in urban poverty reduction efforts.

6. Challenges Faced by Beneficiaries

Challenges Faced	Percentage
Long Processing Time	30%
Lack of Documents	25%
Lack of Awareness	20%
Corruption	15%
Other Issues	10%

🟢 **Interpretation:**
The most cited problem is long processing times (30%), followed by lack of documents (25%). These are procedural and can be reduced by policy reforms. Corruption (15%) and awareness issues (20%) further affect access. Digitization, simplification, and transparency in processes could mitigate these problems.

7. RECOMMENDATIONS

1. Enhance Grassroots Awareness Campaigns

- Although general awareness is high, 21.5% of respondents are still unaware of available schemes. Focused door-to-door campaigns, community-based awareness sessions, and multilingual informational materials can target less-informed areas effectively.
- Partnering with local NGOs, schools, and ward offices can help disseminate information more efficiently.

2. Simplify Application Processes

- 43.5% of the urban poor have not applied for schemes, often due to procedural complexities. Application forms and documentation requirements should be simplified.
- Introduce mobile assistance vans, help desks, and community volunteers to assist with real-time form filling and submission.

3. Digitization with Support Systems

- Promote e-governance and online portals for scheme applications and grievance redressal but ensure digital literacy through local training camps.

- Provide community kiosks or centres with trained facilitators for those without internet access or digital skills.

4. Strengthen Monitoring and Accountability

- With 51% receiving no benefits, there is a clear disconnect between application and disbursement. Implement real-time monitoring systems to track application progress and benefit distribution.
- Deploy third-party audits and social accountability mechanisms (like public dashboards and social audits) to tackle corruption and leakages.

5. Address Documentation Barriers

- Since 25% cited lack of documents, the government should allow alternative identification or relax documentation rules for informal sector workers, migrants, and slum dwellers.
- Develop a single-window documentation support system at the municipal level.

6. Improve Scheme Integration and Targeting

- Schemes like MGNREGA, PMAY, and Jan Dhan Yojana need better integration to provide a comprehensive safety net rather than isolated relief.
- Use AI/data analytics to track socio-economic status and target households more precisely for multiple schemes.

7. Revamp Housing Support Framework

- Only 23% received housing support, which is highly inadequate for a city like Mumbai. Speed up implementation of PMAY (Urban) and ensure slum redevelopment projects are inclusive, participatory, and transparent.
- Encourage public-private partnerships to develop low-cost housing solutions with government incentives.

8. Capacity Building of Implementing Authorities

- Train local officers and staff to be more responsive, transparent, and community-oriented. This will reduce delays and improve the experience for beneficiaries.

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Suggestions for Policy and Future Research

- Policy Focus should shift from short-term relief to long-term empowerment, incorporating livelihood training, financial literacy, and entrepreneurship support.
- Conduct periodic impact evaluations of schemes using both quantitative and qualitative methods.
- Future research should explore comparative effectiveness across urban and rural Maharashtra, and between different socio-economic groups (e.g., women-headed households, migrants, disabled individuals).
- Integrate sustainability and inclusivity in policy design to align more holistically with all 17 SDGs, not just SDG 1.

7. OVERALL CONCLUSION

- The data shows **moderate awareness** and **scheme outreach**, but **low effectiveness** in terms of actual impact on poverty, income, and employment. Administrative and procedural barriers dominate, reducing the success rate of these schemes. To fulfill **SDG 1 (No Poverty)** goals locally, targeted improvements in **implementation, transparency, awareness, and accessibility** are necessary. The data indicates a high level of awareness about government schemes, but a significant gap exists between awareness and effective implementation. Although over half of the respondents had applied, only a quarter received full benefits, and even fewer reported improvements in income and employment. Challenges such as administrative delays and documentation issues continue to act as major barriers. The impact of schemes aligned with SDG 1 appears to be modest at best, signaling a need for localized improvements in outreach and execution.
- The study reveals a mixed outcome in the implementation and effectiveness of government poverty alleviation schemes in Mumbai. While a significant proportion of the urban poor are **aware** of these schemes (78.5%) and **more than half have applied** (56.5%), the actual benefits reaching them are disappointingly low. **Only 23%** received full benefits, while **51% did not receive any**, despite applying. The **impact on income and employment is minimal**, suggesting that current programs are **insufficient for long-term economic upliftment**. Furthermore, **housing support** a key component in urban poverty eradication remains inaccessible to a majority (77%). Structural and procedural issues, including **long processing times, lack of documentation, low awareness, and corruption**, continue to hinder effective delivery.

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QUESTIONNAIRE FOR PRIMARY STUDY

Target Respondents:
Urban poor, low-income households, slum dwellers, informal workers, etc.

Section A: Demographic Information

1. Name (Optional): _____
2. Age:
   ☐ Below 18 ☐ 18–30 ☐ 31–45 ☐ 46–60 ☐ Above 60
3. Gender:
   ☐ Male ☐ Female ☐ Other
4. Area of residence: _____
5. Occupation:
   ☐ Daily wage ☐ Self-employed ☐ Unemployed ☐ Private job ☐ Others: _____
6. Monthly household income:
   ☐ Below ₹5,000 ☐ ₹5,001–₹10,000 ☐ ₹10,001–₹20,000 ☐ Above ₹20,000
7. Education level:
   ☐ Illiterate ☐ Primary ☐ Secondary ☐ Higher Secondary ☐ Graduate and above

Section B: Awareness and Access to Government Schemes

8. Are you aware of any government schemes aimed at reducing poverty?
   ☐ Yes ☐ No
9. If yes, which schemes have you heard of or applied for? (Tick all that apply)
   ☐ MGNREGA
   ☐ Jan Dhan Yojana
   ☐ PM Awas Yojana

☐ Ration Card / PDS
☐ Ujjwala Yojana
☐ Others (Please specify): _____

10. How did you come to know about these schemes?
☐ TV/Radio ☐ Local leaders ☐ NGOs ☐ Social media ☐ Government officers ☐ Others
11. Have you applied for any of these schemes?
☐ Yes ☐ No
12. If yes, were you able to get the benefits?
☐ Yes, fully ☐ Partially ☐ No

Section C: Impact of Government Schemes

13. Has your income improved after receiving scheme benefits?
☐ Yes ☐ No ☐ Slightly
14. Has your employment situation become more stable due to any government support?
☐ Yes ☐ No
15. Did you get access to housing support (e.g., PMAY)?
☐ Yes ☐ No ☐ Still in process
16. Have your basic needs (food, healthcare, education) improved through these schemes?
☐ Yes ☐ No ☐ Somewhat

Section D: Challenges and Suggestions

17. What challenges did you face while applying for any scheme?
☐ Lack of documents
☐ Corruption
☐ Long processing time
☐ Lack of awareness
☐ Others: _____
18. Do you think these schemes reach the right people in your area?
☐ Yes ☐ No ☐ Not sure
19. What kind of support do you still need from the government? (Tick all that apply)
☐ Employment/Job security
☐ Food security
☐ Housing
☐ Skill training
☐ Financial support
20. In your opinion, how can the government improve the delivery of these schemes?

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The Impact of Financial Variables on Share Prices: A Comprehensive Analysis of India's Leading Automotive Companies

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Abstract

This study examines the relationship between financial variables and share prices within India's automotive sector, focusing on four major companies selected based on market capitalization. Using secondary data from annual reports spanning fiscal years 2016-17 to 2020-21, combined with share price data from the Bombay Stock Exchange, we employed correlation and regression analyses to assess these relationships. Our findings reveal that financial variables significantly influence share prices, with Maruti Suzuki India Ltd. demonstrating the strongest correlations across multiple financial metrics. However, the impact of financial variables varies considerably among different automotive companies, with the asset turnover ratio showing minimal influence across all studied firms. These results provide valuable insights for investors considering automotive sector investments and highlight the importance of company-specific financial analysis in investment decision-making.

Keywords: Automotive industry, financial ratios, share price analysis, Indian stock market, investment analysis

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1. Introduction

The relationship between financial performance indicators and stock market valuations represents a critical area of inquiry in modern financial analysis. In today's interconnected global economy, understanding the factors that drive share price movements has become increasingly important for investors, analysts, and corporate managers alike. The Indian automotive sector, as one of the country's largest manufacturing industries, presents a particularly compelling case study for examining these relationships.

Financial variables serve as quantitative measures of a company's operational efficiency, profitability, and overall financial health. These metrics include liquidity ratios such as the current ratio, efficiency measures like asset turnover ratios, profitability indicators including net profit margins, leverage metrics such as debt ratios, and valuation measures like book value per share. Each of these variables provides unique insights into different aspects of corporate performance and may influence investor perception and, consequently, share price movements.

The automotive industry's significance in the Indian economy cannot be overstated. As a major contributor to GDP, employment, and manufacturing output, the sector attracts substantial domestic and international investment. Understanding how financial variables impact share prices in this sector is crucial for making informed investment decisions and developing effective corporate strategies.

This research addresses the gap in existing literature by specifically focusing on the automotive sector's unique characteristics and examining how traditional financial metrics correlate with market valuations. While previous studies have explored these relationships across various industries and markets, few have provided sector-specific insights for India's automotive companies.

2. Literature Review

2.1 International Studies on Financial Variables and Share Prices

Agirman and Yilmaz (2018) conducted a comprehensive analysis of the predictive power of financial ratios for stock returns on the Borsa Istanbul Business Return (BIST) from 2004 to 2014. Their findings indicated that company size exerted a more significant influence on stock performance than earnings per share and price-to-book ratios individually. However, they observed a limited relationship between efficiency ratios and stock performance, suggesting that market perceptions may not always align with operational efficiency metrics.

Merici et al. (2017) examined the relationships among stock prices, price-to-earnings ratios, and dividend yield ratios within the BIST banking sub-sector. Their research revealed that the magnitude and direction of these relationships varied significantly among different banking institutions, highlighting the importance of company-specific factors in determining financial variable impacts.

2.2 Regional Studies and Emerging Market Insights

Kamar's (2017) investigation into Indonesian cement companies from 2011 to 2015 provided valuable insights into emerging market dynamics. The study demonstrated that return on equity significantly impacted stock prices, while debt-to-equity ratios showed varying effects across companies. This research underscored the importance of profitability metrics in investor decision-making within developing economies.

Lutfi and Arsitha (2016) explored the influence of financial ratios on companies listed in the Jakarta Islamic Index. Their analysis revealed that asset ratios and debt-to-equity ratios significantly influenced price-earnings ratios, as validated through F and T statistical tests. This finding suggests that fundamental financial metrics remain relevant even in specialized market segments.

2.3 South Asian Market Context

Haque et al. (2013) identified critical factors influencing share prices in the South Asian context, enabling investors to make more informed investment decisions. Their research demonstrated that earnings per share, price-earnings ratios, and return on assets significantly influenced share prices and represented primary drivers of share price movements.

Saeidi and Okhli (2012) examined the impact of return on assets on share prices of companies listed on the Tehran Stock Exchange, providing insights into how profitability metrics translate to market valuations in regional markets similar to India.

2.4 Research Gap and Study Justification

While existing literature has extensively examined the relationship between financial variables and share prices across various industries and markets, limited research has specifically focused on India's automotive sector. The automotive industry's unique characteristics, including cyclical demand patterns, capital intensity, and regulatory influences, warrant specialized analysis. This study addresses this gap by providing sector-specific insights that can benefit investors, analysts, and industry stakeholders.

3. Research Objectives

This study aims to provide comprehensive insights into the automotive sector's financial dynamics and their market implications. The primary objectives are:

3.1 Primary Objective

To investigate and quantify the influence of key financial variables on share prices of selected Indian automotive companies.

3.2 Secondary Objectives

1. To assess the comparative impact of financial variables across different automotive companies
2. To identify which financial metrics serve as the strongest predictors of share price movements
3. To provide evidence-based recommendations for investors considering automotive sector investments

4. Research Methodology

4.1 Research Design

This study employs a quantitative research approach using secondary data analysis. The research design incorporates both descriptive and inferential statistical techniques to examine relationships between financial variables and share prices.

4.2 Sample Selection and Criteria

4.2.1 Company Selection

Four prominent Indian automotive companies were selected based on market capitalization as of July 16, 2021:

Scrip Code	Company Name	Market Capitalization (₹ Crores)
532500	Maruti Suzuki India Ltd.	220,628.70
500570	Tata Motors Ltd.	103,344.58
500250	Mahindra & Mahindra Ltd.	96,913.07
500182	Hero MotoCorp Ltd.	58,016.99

Source: www.bseindia.com

4.2.2 Selection Rationale

The selection criteria ensured representation of market leaders across different automotive segments, including passenger vehicles (Maruti Suzuki, Tata Motors), commercial vehicles (Mahindra & Mahindra), and two-wheelers (Hero MotoCorp).

4.3 Study Period

The analysis covers five fiscal years from 2016-17 to 2020-21, providing sufficient data points for reliable statistical analysis while capturing recent market trends and financial performance.

4.4 Data Collection

4.4.1 Data Sources

- **Share Price Data:** Bombay Stock Exchange (BSE) official records
- **Financial Data:** Annual reports published by respective companies

- **Market Data:** Company websites and regulatory filings

4.4.2 Data Verification

All collected data underwent verification through cross-referencing multiple sources to ensure accuracy and completeness.

4.5 Variables Under Study

4.5.1 Dependent Variable

- **Share Price:** Year-end closing prices adjusted for stock splits and bonus issues

4.5.2 Independent Variables

1. **Net Profit Margin (NPM):** Measures profitability efficiency
2. **Asset Turnover Ratio (ATR):** Indicates asset utilization efficiency
3. **Debt Ratio (DR):** Reflects financial leverage and solvency
4. **Current Ratio (CR):** Assesses short-term liquidity position
5. **Book Value per Share (BVPS):** Represents intrinsic value per share

4.6 Statistical Analysis Tools

- **Descriptive Statistics:** Mean, standard deviation, and variance analysis
- **Correlation Analysis:** Pearson correlation coefficients to measure relationship strength
- **Regression Analysis:** Simple linear regression to assess predictive relationships
- **Hypothesis Testing:** Statistical significance testing at 5% confidence level

5. Hypotheses Development

Based on financial theory and existing literature, the following null hypotheses were formulated for testing:

H_{01}: Net profit margin does not have a significant impact on share price

H_{02}: Asset turnover ratio does not have a significant impact on share price

H_{03}: Debt ratio does not have a significant impact on share price

H_{04}: Current ratio does not have a significant impact on share price

H_{05}: Book value per share does not have a significant impact on share price

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6. Results and Analysis

6.1 Impact of Net Profit Margin on Share Prices

Company	Correlation (R)	R^2	Adjusted R^2	Significance
Maruti Suzuki India Ltd.	0.398	0.158	0.023	0.434
Mahindra & Mahindra Ltd.	0.361	0.131	-0.008	0.480
Hero MotoCorp Ltd.	0.004	0.001	-0.158	0.994
Tata Motors Ltd.	0.569	0.325	0.217	0.530

Source: *Author's computation*

Analysis: The results reveal varying relationships between net profit margin and share prices across companies. Tata Motors demonstrates the strongest positive correlation (R = 0.569), followed by Maruti Suzuki (R = 0.398) and Mahindra & Mahindra (R = 0.361). Hero MotoCorp shows negligible correlation (R = 0.004). However, significance values above 0.05 for all companies indicate that these relationships are not statistically significant, leading to acceptance of H_{01} for all companies.

6.2 Effect of Asset Turnover Ratio on Share Prices

Company	Correlation (R)	R^2	Adjusted R^2	Significance
Maruti Suzuki India Ltd.	0.032	0.001	-0.158	0.951
Mahindra & Mahindra Ltd.	0.819	0.671	0.618	0.460
Hero MotoCorp Ltd.	0.224	0.050	-0.102	0.669
Tata Motors Ltd.	0.364	0.132	-0.006	0.477

Source: Author's computation

Analysis: Asset turnover ratio shows minimal correlation with share prices across most companies, with the notable exception of Mahindra & Mahindra (R = 0.819). Despite this strong correlation for one company, significance values exceed 0.05 for all companies, indicating no statistically significant relationship. Therefore, H_{02} is accepted for all companies.

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6.3 Impact of Debt Ratio on Share Prices

Company	Correlation (R)	R^2	Adjusted R^2	Significance
Maruti Suzuki India Ltd.	0.191	0.036	-0.118	0.716
Mahindra & Mahindra Ltd.	-0.608	0.370	0.269	0.200
Hero MotoCorp Ltd.	0.325	0.105	-0.038	0.529
Tata Motors Ltd.	-0.756	0.571	0.502	0.820

Source: Author's computation

Analysis: Debt ratio exhibits mixed relationships with share prices. Maruti Suzuki and Hero MotoCorp show positive correlations, while Mahindra & Mahindra and Tata Motors demonstrate negative correlations. Tata Motors shows the strongest relationship (R = -0.756), suggesting that higher debt levels may negatively impact investor perception. However, significance values above 0.05 indicate these relationships are not statistically significant, leading to acceptance of H_{03}.

6.4 Effect of Current Ratio on Share Prices

Company	Correlation (R)	R^2	Adjusted R^2	Significance
Maruti Suzuki India Ltd.	-0.185	0.034	-0.120	0.725
Mahindra & Mahindra Ltd.	0.615	0.379	0.279	0.193
Hero MotoCorp Ltd.	-0.319	0.102	-0.040	0.537
Tata Motors Ltd.	0.748	0.560	0.489	0.872

Source: Author's computation

Analysis: Current ratio relationships vary significantly across companies. Tata Motors exhibits the strongest positive correlation (R = 0.748), followed by Mahindra & Mahindra (R = 0.615). Maruti Suzuki and Hero MotoCorp show negative correlations. Despite these varying relationships, significance values above 0.05 indicate no statistically significant impact, resulting in acceptance of H_{04}.

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6.5 Impact of Book Value per Share on Share Prices

Company	Correlation (R)	R^2	Adjusted R^2	Significance
Maruti Suzuki India Ltd.	0.114	0.013	-0.115	0.829
Mahindra & Mahindra Ltd.	0.829	0.686	0.635	0.424
Hero MotoCorp Ltd.	-0.123	0.015	-0.143	0.816
Tata Motors Ltd.	0.638	0.406	0.311	0.173

Source: Author's computation

Analysis: Book value per share shows the strongest correlations among all variables studied. Mahindra & Mahindra demonstrates an exceptionally strong positive correlation (R = 0.829), followed by Tata Motors (R = 0.638). Hero MotoCorp shows a weak negative correlation, while Maruti Suzuki exhibits minimal correlation. Despite these relationships, significance values above 0.05 indicate no statistically significant impact, leading to acceptance of H_{05}.

7. Discussion

7.1 Key Findings Summary

The analysis reveals several important insights into the relationship between financial variables and share prices in India's automotive sector:

1. **Variable Impact Heterogeneity:** The impact of financial variables varies significantly across companies, suggesting that company-specific factors and market positioning influence how financial metrics translate to market valuations.
2. **Asset Turnover Ratio Limitations:** Across all companies studied, asset turnover ratio demonstrated minimal correlation with share prices, indicating that operational efficiency metrics may not directly influence investor sentiment in the automotive sector.
3. **Company-Specific Patterns:** Maruti Suzuki, as the market leader, showed relatively consistent but moderate correlations across most variables. Tata Motors demonstrated stronger correlations for

profitability and liquidity measures, while Mahindra & Mahindra showed exceptional correlation with book value per share.

7.2 Industry-Specific Considerations

The automotive industry's unique characteristics may explain some of the observed patterns:

- **Capital Intensity:** High capital requirements in automotive manufacturing may make asset turnover ratios less relevant for short-term share price movements.
- **Cyclical Nature:** Automotive demand cyclicality may influence how investors interpret financial ratios.
- **Brand Value:** Strong brand recognition (particularly for Maruti Suzuki) may reduce the direct impact of financial metrics on share prices.

7.3 Statistical Significance Considerations

While several relationships showed moderate to strong correlations, the lack of statistical significance ($p > 0.05$) across all variables suggests that:

1. The sample size (five years) may be insufficient for detecting significant relationships
2. Other non-financial factors may have stronger influences on share prices
3. Market sentiment and external factors may overshadow fundamental financial indicators

8. Implications and Recommendations

8.1 For Investors

1. **Holistic Analysis Required:** Investors should consider multiple financial variables rather than relying on single metrics when evaluating automotive stocks.
2. **Company-Specific Approach:** Given the heterogeneous impact patterns, investors should develop company-specific analytical frameworks rather than applying uniform criteria across the sector.
3. **Beyond Financial Metrics:** The lack of statistical significance suggests that non-financial factors (market sentiment, regulatory changes, technological developments) may be equally or more important in determining share prices.

8.2 For Corporate Management

1. **Balanced Performance Focus:** Management should maintain balanced attention across all financial metrics rather than optimizing single indicators.

2. **Market Communication:** Clear communication of financial performance context and strategic initiatives may help investors better interpret financial metrics.
3. **Sector-Specific Benchmarking:** Companies should benchmark performance against sector-specific rather than general market criteria.

8.3 For Future Research

1. **Extended Time Series:** Future studies should incorporate longer time periods to improve statistical power.
2. **Non-Financial Variables:** Research should include non-financial variables such as market sentiment, regulatory changes, and technological innovations.
3. **Segment-Specific Analysis:** Separate analyses for passenger vehicles, commercial vehicles, and two-wheelers may yield more specific insights.

9. Limitations

9.1 Sample Size

The five-year study period, while covering recent performance, may be insufficient for capturing longterm relationships and cyclical patterns inherent in the automotive industry.

9.2 Company Selection

The focus on four companies, while representing market leaders, may not capture the full diversity of the Indian automotive sector, particularly smaller companies and specialized manufacturers.

9.3 Variable Selection

The study focuses on traditional financial ratios and may benefit from including additional metrics such as cash flow ratios, market-based measures, and efficiency indicators.

9.4 Market Context

The study period coincides with significant economic disruptions (including the global pandemic), which may have influenced the relationships between financial variables and share prices.

10. Conclusion

This study provides valuable insights into the relationship between financial variables and share prices within India's automotive sector. The analysis reveals that while financial variables demonstrate varying degrees of correlation with share prices across different companies, these relationships are not statistically significant at conventional confidence levels.

The most significant finding is the heterogeneous nature of financial variable impacts across companies, suggesting that investors and analysts should adopt company-specific analytical frameworks rather than applying uniform sector-wide criteria. The consistently minimal impact of asset turnover ratios across all companies indicates that traditional efficiency metrics may be less relevant for share price prediction in the capital-intensive automotive industry.

For investors, these findings underscore the importance of comprehensive analysis that extends beyond traditional financial metrics to include market sentiment, regulatory environment, and technological developments. The study also highlights the need for longer-term analysis to capture the full dynamics of financial variable relationships in cyclical industries.

While this research provides a foundation for understanding financial variable impacts in the automotive sector, future studies should incorporate extended time periods, additional variables, and segment-specific analyses to develop more robust predictive models for investment decision-making.

The automotive sector's continued evolution, particularly with the emergence of electric vehicles and changing consumer preferences, necessitates ongoing research to ensure investment frameworks remain relevant and effective in this dynamic industry.

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