Volume 02 Number 02 May - August 2025
(A Peer Reviewed Research Journal)
ISSN No: 2349-6355

गुरुर्गुरुतमो धाम
NCTE

INDIAN JOURNAL of TEACHER EDUCATION

National Council for Teacher Education
New Delhi

INDIAN JOURNAL OF TEACHER EDUCATION (IJTE)

[ISSN 2349-6355]

AIMS AND SCOPE

The Indian Journal of Teacher Education (IJTE) is a peer reviewed International Journal published by the National Council for Teacher Education (NCTE), New Delhi (a statutory body of Government of India) three times a year, i.e. in April, August and December. It aims at engaging with policy, theory, research and practice in teacher education and their interface at different levels of education. It also intends to create a forum for academic discussions, debates and other forms of exchange of ideas in teacher education among different stakeholders. It encourages multi-disciplinary, comparative and praxis based analysis in the domain of teacher education regionally and globally.

To realize these aims, the journal invites reflective articles, research papers, critical reviews, philosophical analysis of concepts and theories of education, book reviews and commentaries on both historical and contemporary issues and concerns in a variety of areas involving professional development of teachers and teacher educators, experiential accounts of educational practitioners, and ethical and quality concerns in teacher education. Views expressed by authors belong to them, and not to NCTE.

Published by **Ms. Sukhgeet Kaur,** IOFS, Member Secretary, National Council for Teacher Education, New Delhi and printed at Daya Printers, Kotla Mubarakpur, New Delhi

Cover Design by IT Division, National Council for Teacher Education, New Delhi

Volume 02 Number 02 May - August 2025 **ISSN 2349-6355**

IJTE
INDIAN JOURNAL OF TEACHER EDUCATION

NATIONAL COUNCIL FOR TEACHER EDUCATION
NEW DELHI - 110075

Reflection

NEP 2020 to Viksit Bharat @2047: A Special Focus on Teacher Education in India

The National Education Policy (NEP) 2020 marks a historic transformation of India's education system in the 21st century and stands out as one of the most significant socio-economic and educational reforms, aimed at steering the nation's journey from "India" to a "Viksit Bharat" by 2047. Teacher education is most important aspect of NEP-2020, under the vision of Prime Minister Shri Narendra Modi ji, which symbolizes the shift from "incremental changes" to "holistic transformation" in the education system for "building the nation into Vikshit Bharat." As, NEP-2020 is in its sixth year of implementation, it is important to engage with how the philosophical underpinning, governance transformation, and technology shift is impacting Teacher Education and how it is shaping the future development agendas for "Bharat." In this reflection paper, an attempt has been made to light on NEP 2020, teacher education, India's civilization values, modern changes in governance structures, development of Artificial Intelligence and its implication to education, and subsequent social economic consequences in harmony with the pursuit of Viksit Bharat @ 2047.

The philosophical underpinning of NEP 2020 lies in the civilisational and cultural philosophy of India, which holds education as holistic, multidisciplinary, and integrated process of development of the intellect, morals, and social character. Instead, it appeals to the philosophy that education aims at developing qualities, morals, social commitments, and national awareness alongside knowledge and technical skills. Its philosophical basis is in sync with the ideas of Pandit Deendayal Upadyay's Integral Humanism Philosophy, stressing all-around growth and development. The NEP-2020 embraces the educational vision expressed by visionaries such as Atal Bihari Vajpayee, who envisioned education as the foundation for a self-dependent, robust Indian nation. Teachers, under this rubric, are more than just pedagogues; they are mentors, nation builders, and are entrusted with creating illumined and responsible Indian citizens.

Moreover, this policy relies on the constructivist learning approaches, which emphasizes critical reflection and questioning, practice-based learning etc. This also emphasis the vision of Prime Minister, Shri Narendra Modi, that India must become a learning society where teachers themselves also develop by learning through mentorship and online platforms.

Viksit Bharat @2047 and the Central Role of Teacher Education

In hundred years of independence and the vision of "Viksit Bharat @2047" outlined the framework of prosperity and equity, technology leadership, and values of governance. Education is placed at the core of the proposed change, and teacher education is seen as its most essential pillar. Thoughtfully, it may be observed that the NEP 2020 is cognizant of the fact that merely through policy frameworks and infrastructure, it is impossible to transform a nation. Such transformation only happens in the classroom, and it is here that teachers can influence the values, skills, and aspirations of learners. By emphasizing teacher education reforms, the policy considered, teachers as human capital for developing an innovative and responsible social cohort for an Vikshit Bharat.

NEP 2020 has visualized a multidisciplinary and research-centric higher education system where teacher education is also in a transformational phase. This is encapsulated in this policy document by starting the 4-year Integrated Teacher Education Programme (ITEP), where teacher education will become an integral part of a multidisciplinary Higher Educational Institution. Reflected upon is how the integration will improve the academic credentials and status of teacher education. The teacher education environment will help train teachers who can contribute to problem-based teaching, research, and innovation. The coming together of these components will improve both school and higher education and make teacher education one of the key components of Indian Knowledge System.

One of the main structural reforms proposed under NEP 2020 is the setting up of the Viksit Bharat Shiksha Adhishthan Bill (VBSA Bill), 2025 to ensure a rational governance structure by decoupling the functions of regulation, accreditation, financing, and setting of standards. This is a reflection of the overall governance approach of the present government, which is based on the ideology of "minimum government, maximum governance."

As regards teacher education, this heralds a paradigm shift for educators from regulative models that are disjointed and compliance-oriented to those that are standards-related and outcome-oriented. Regulatory bodies like NCTE are gradually making way from control models to models that focus on assurance/ benchmarking with respect to quality/ academic standards. As regards reflective consideration, although reform in governance is imperative and needed, it is contingent on institutional capability and cooperative federalism between states and autonomous entities.

Teacher Education Reforms: Technological, Social & Economic Impacts

Teacher education needs continuous transformation in response to rapid educational change due to technological progress. Digital technologies, diverse learner needs, and increasing expectations from teachers mean that contemporary classrooms look very

different from those most teachers currently experience in their pre-and in-service training. The traditional model of teacher education is still largely theory-driven and examination-oriented; it no longer provides an adequate preparation for these complex realities.

One major concern is the persistent gap between pedagogical theory and classroom practice. Newly trained teachers often struggle to manage real-life challenges like inclusive pedagogy and classrooms, learner diversity, and contextual constraints. Teacher education should therefore be more practice-based, reflective, and responsive to school realities. Moreover, digitalization in this present era, along with the era of data analytics and artificial intelligence, requires that teachers better equip themselves with digital and ethical competencies. Programs in teacher education need to integrate technology within pedagogy rather than present it as an optional skill. Of equal importance is the continuously changing social role of teachers as mentors, facilitators, and lifelong learners. Nowadays, teachers are recommended to develop critical thinking, creativity, empathy, and socio-emotional skills among students. It is for this reason that strengthening teacher education becomes necessary and important, not only for classroom improvement but also for developing the professional identity of teachers and promoting an education system that is both inclusive and future ready.

The restructuring of teachers' education through NEP 2020 has wide socio-economic implications, placing teachers at the forefront of an inclusive paradigm of national development. Upgraded teachers' education facilitates equal learning achievements, especially in rural, tribal, and marginalized sections of society, through the implementation of an inclusive-learning approach. Besides contributing to equal educational achievements, teachers are social transformers in schools and societies, inculcating constitutional values of national unity, gender equity, and democratic citizenship. At the same time, upgrading teachers' education through continuous investment in human capital development of teachers yields immense long-run economic benefits. Upgraded teaching enables improved leaning achievements, employability of students, and innovation-induced economic growth – essential requirements in India's march towards a knowledge economy. In line with its ambition of attaining global competitiveness in its "Viksit Bharat @2047" vision of development, teachers' education needs to move beyond its characterization as a "social service" cost and should feature instead in India's strategic national investment portfolio of multifunctional dividends in social integration and economic sustainability.

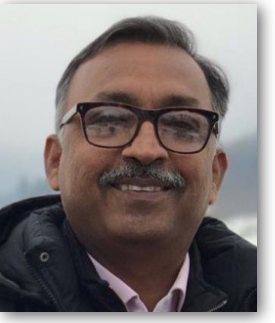
When NEP-2020 is analyzed through the lance of "Viksit Bharat @2047", it is apparent that "teacher education is the linchpin of the developmental vision of India." Drawing from the philosophical foundations, through the sagacity of its political leadership, because of governance reforms, and in response to technological advancements, the reforms in teachers' education have the potential to "transform the educational, social,

and economic landscape" of the country.

With the forthcoming completion of the first century after the gaining of Indian independence, the task before teachers will not only be to implement the reforms, but teachers themselves would lay the foundations for the intellectual, moral, and economic development of the nation, and therefore the task before aspiring and qualified teachers themselves will not only be to seek education, but to invest in building a Viksit Bharat.

Prof. Pankaj Arora
Chairperson
National Council for Teacher Education (NCTE)

From the Editor's Desk



It gives me immense pleasure to present Volume 2, Number 2 of the Indian Journal of Teacher Education, an academic initiative of the National Council for Teacher Education (NCTE). This issue explores the role of teacher education in the larger vision of Viksit Bharat @2047, with particular attention to its changing priorities, responsibilities and future direction.

India's journey towards Viksit Bharat @2047 places education at the heart of national development, with teachers at the centre of this endeavour. In this context, the National Education Policy 2020 has renewed the focus on teacher education, particularly on preparing competent and reflective teachers who can respond effectively to the changing needs of learners and classrooms.

Teacher education in India is undergoing an important phase of transition, with ongoing reforms giving new direction to teacher preparation and professional practice. The four-year Integrated Teacher Education Programme (ITEP) takes this transition forward by bringing teacher preparation into multidisciplinary institutions and strengthening its connection with classroom practice. At the same time, the evolving institutional and regulatory framework is placing greater emphasis on quality, academic standards and professional responsibility. The growing integration of digital technologies and Artificial Intelligence is further expanding the possibilities for teaching and learning and reshaping the professional role of teachers. Together, these developments require us to look beyond teacher preparation as a pathway to acquiring a professional qualification. Teacher education must prepare educators who can connect knowledge with practice, respond to learner diversity, uphold constitutional and ethical values, and continue to develop throughout their professional lives.

Today's classrooms bring together learners from diverse linguistic, cultural, social and economic backgrounds. Teachers are therefore expected not only to teach subject knowledge, but also to create inclusive learning environments, nurture curiosity and creativity, and help learners develop the judgement and values required to participate responsibly in society. These responsibilities require teacher education to remain closely connected to school realities while preparing teachers for emerging educational contexts.

At the same time, the future of teacher education must remain rooted in India's educational and cultural traditions. Indian educational thought has long emphasised the development of knowledge, values, social responsibility and the individual as a whole. NEP 2020 carries these principles into the contemporary educational context. Teacher education institutions have an important responsibility to translate this vision into practice by bringing Indian educational values into meaningful engagement with research, innovation and technology.

This wider responsibility assumes particular importance in the context of India's development aspirations. The journey towards a developed India depends not only on infrastructure, technology and economic progress, but also on informed, capable, responsible and compassionate citizens. Teachers help shape the knowledge, values and sense of responsibility that young people carry into society. The quality of teacher education will therefore influence not only the future of our classrooms and institutions, but also the character and direction of India's progress towards Viksit Bharat @2047.

The journal provides a space to reflect on these developments and engage with the changing landscape of teacher education in India. The contributions bring together perspectives from research, policy, practice and institutional experiences. They offer insights into the relationship between policy aspirations and institutional realities, while drawing attention to the responsibilities of teacher education institutions as the sector continues to evolve. Such academic engagement can strengthen dialogue among teacher educators, researchers, policymakers, institutions and practitioners.

I hope this issue encourages readers not merely to engage with the ideas presented here, but to carry these conversations into their institutions, research and professional practice. Educational reform acquires meaning when its principles are understood thoughtfully, interpreted in context and reflected in educational practice. As members of the teacher education community, we share the responsibility of ensuring that the aspirations of NEP 2020 find meaningful expression in the preparation and professional development of teachers.

I congratulate the editorial team and all the contributors who have brought this issue together. I am confident that the journal will continue to serve as a credible academic platform for sharing research, experiences and informed perspectives, and will contribute meaningfully to the continuing discourse on teacher education in India.

Warm regards,

Professor Amit Kauts
Head, Department of Education,
Guru Nanak Dev University, Amritsar, Punjab

INDIAN JOURNAL OF TEACHER EDUCATION

[ISSN 2349-6355]

Volume 02 Number 02 May-August 2025

CONTENTS

PAPERS	**Page**
Students' Perspectives on Community Engagement within Higher Education Institutions *Rafi Mohmad*	1-16
Pedagogical Innovation through STEM Integrated Study on Yeast Fermentation *Dr. Monideepa Mukhopadhyay*	17-31
Role of Metacognition and Critical Thinking in Predicting ICT Acceptance among Pre-service Teachers *Dr. Anamika Yadav*	32-45
Technology-Integrated Formative Assessment in Secondary School Mathematics: A Systematic Review *Shivam Tripathi*	46-59
Study on the Impact of School Leadership on Equity and Quality in Education: An Empirical Analysis of Transformational, Instructional, and Distributive Leadership Models *Dipak Karmakar*	60-78
Continuous Professional Development In India: From Policy Mandate to Transformative Practices under NEP 2020 *Apoorva Chaturvedi*	79-95
BOOK REVIEW	
How Learning Works: Seven Research-Based Principles for Smart Teaching Prof. Asheesh Srivastava	96-98

Indian Journal of Teacher Education, 2025 2(2), 1-16

Students' Perspectives on Community Engagement within Higher Education Institutions

Rafi Mohmad
Department of Education and Training, MANUU
rafimdedu@gmail.com

Abstract: Community engagement is crucial for holistic development and social responsibility among students. This paper explores the perspective of undergraduate students towards community engagement within higher education institutions (HEIs). The paper envisaged to find out the perceived level of community engagement, barriers, and best practices among students. A quantitative approach was employed and descriptive survey method was used. The sample of the study comprised of 218 undergraduate students from government degree colleges in Hyderabad. Findings revealed varying levels of perceptions of community engagement. Female students showed a significantly higher perception of community engagement compared to male students. While discipline did not significantly influence overall community engagement, differences were observed in curriculum engagement and perceived barriers.

Keywords: Community Engagement, Social Responsibility, Students' Perception, Higher Education Institutions

Introduction

Community plays a vital role in providing vision to an individual to grow, dream big and work towards achieving desired goals in life. Community is often considered as one of the important informal agencies of education, it's the community and its members who contribute largely to the overall development of the children. Community engagement thus must be an integral aspect that must be observed among the students of higher education as it is imperative for students at this stage to become aware of societal needs, challenges, and aspirations, and to begin planning how to serve and contribute meaningfully to their communities.. Higher Education Institution (HEI) carries a major responsibility to create awareness and inculcate community engagement practices among their students.

Community engagement encompasses several key aspects that are vital for fostering meaningful connections between institutions and communities. Conducting research that addresses community needs is fundamental, as it ensures that academic inquiries are relevant and beneficial to society, addressing pressing social, economic, and environmental issues (Stoecker, 2005). Service and outreach initiatives are also critical, as they enable institutions to provide direct support to communities, promoting social responsibility and civic engagement among participants (Bringle & Hatcher, 2002). Building sustainable relationships with community organizations is essential for the long-term success of these efforts, ensuring that engagement activities are well-coordinated and mutually beneficial (Furco, 2010). For instance, collaborative partnerships between universities and local non-profits can lead to innovative solutions for community challenges while providing valuable experiential learning opportunities for students (Worrall, 2007). These aspects collectively amplify the value and outcomes of community-oriented activities, leading to a flow of knowledge and support between educational institutions and the populations they aim to serve.

Community engagement in higher educational institutions (HEIs) is vital for fostering a holistic academic environment that benefits both students and the wider community. Through integrating service-based projects into coursework, students gain opportunities to translate academic theories into practical, real-life applications. This method of learning through experience not only enhances students' academic skills but also cultivates a sense of civic responsibility. For instance, the University of Delhi has incorporated community engagement into its curriculum through projects that address local social issues, providing students with practical experience while benefiting the community (Bhattacharyya, 2018). The Indian Institute of Technology Madras (IIT Madras) involves students in rural development projects, enhancing local infrastructure and educational outcomes (IIT Madras, 2020). Community engagement forms a supportive association between the students, teachers and institutions. It serves as a medium of building collaboration between parents, local business, social bodies, and community leaders to generate an encouraging environment for learning. Community engagement facilitates students with practical learning experiences.

In this regard, University Grant Commission (UGC) issued guidelines titled "Fostering Social Responsibility & Community Engagement in Higher Education Institutions in India 2.0" in December, 2022, under the flagship of Unnat Bharat Abhiyaan (UBA) a programme of Ministry of Education, Government of India.

UBA 2.0 launched in February 2018 was designed to transform rural areas by establishing close collaborations between colleges and rural populations and to bring a revolutionary shift in rural society by promoting research among students. These guidelines consider suggestions proposed by National Education Policy (NEP) 2020 and also take into account the circumstances of pandemic. The document emphasise the prominent role

that HEIs needs to play by exercising active community participation and contributing towards socio-economic development of the nation. The guidelines state that:

"To achieve the objectives of the socio-economic development of New India, HEIs can play an important role through active community engagement. This approach will also contribute to improve the quality of both teaching and research in HEIs in India. As a growing and large sector in the country, HEIs need to foster social responsibility and community engagement in their vision and mission itself. It is also important that institutional mechanisms are developed to adopt a holistic and functional approach to community engagement, encompassing all three functions of HEIs—teaching, research and service." (p. 1)

UGC has set up Subject Expert Groups (SEG) in 2018 under UBA 2.0 to reframe the curricula in such a way that it develops the sense of social responsibility and create a concept of rural community engagement among the students. This paper reflects on how far those objectives have been achieved by examining students' understanding and viewpoints regarding their institutions' civic outreach efforts.

Literature Review

Community engagement has been defined as "a strategic process with the specific purpose of working with identified groups of people, whether they are connected by geographic location, special interest, or affiliation to identify and address issues affecting their well-being." (Department of Agricultural Economics, Sociology, and Education, PennState College of Agricultural Sciences). It further elaborates that by linking the term 'community' with the term 'engagement', it has widened the scope by sliding the spotlight from an individual to a group, carrying along with related connotations towards inclusiveness by covering all the consideration linked with diverse nature of any community.

Community engagement has been defined in numerous contexts based on the way it has been perceived by the authors. 'Community' in community engagement has at times been confined to the family and the neighbouring areas (geographical surroundings) of the students and the educational institutions and at times the lens has widened its reach encompassing the entire globe as a community.

Muwanguzi, Dickens, & Kibaya (2023) reference Bringle and Hatcher's (2002) explanation of community engagement as "the partnership of college and university knowledge and resources with those of the public and private sectors to enrich scholarship, research, and creative activity; enhance curriculum, teaching, and learning; prepare educated, engaged citizens; strengthen democratic values and civic responsibility; address critical societal issues; and contribute to the public good" (p. 5). Various studies affirm that community engagement is a core component of higher education institutions' civic responsibilities

and democratic accountability that a higher education institution holds and can act as a benefactor to the it as well as the community they share their services with.

Studies made to develop and understand the influence of community engagement have revealed that these efforts played a positive role in retaining the students and their completion of course. It has also increased affinity towards institution and lowered workplace stress among the faculty. It made student-teacher-community association better thereby contributing in better exchange of knowledge and resources (Huckett, Graham, & Stewart, 2022). Related studies have also emphasised on including credit based module on community engagement in curricula as a mandate (Mittal & Jora, 2023; Kavatekar, 2018). Students are a part of the community and the research based projects within the community will not only bring HEIs, students and the community on a single platform but will also provide the students an opportunity to know the expertise available aroung them within the community apart from the teachers from whom they gain formal education. This practical aspect will help enrich student experiential learning and development. (Mittal & Jora, 2023; Jordaan & Mennega, 2021). Studies have also emphasised the necessity of the government initiatives in achieving the aims of community engagement by addressing the barriers and challenges which an higher education institution may face. An effort by the government must be given to the HEIs to encourage research in various areas addressing the issues and needs of the society. (Kavatekar, 2018; Alzyoud & Bani, 2015).

Objectives of the study

This study aims to:

1. Assess how undergraduate students perceive community engagement within HEIs
2. Explore the barriers and challenges encountered in the execution of community engagement initiatives from students' point of view
3. Determine the best practices for implementing community engagement from students' point of view
4. Find out gender-based differences in how students perceive community engagement in HEIs
5. Find out locale-based differences in how students perceive community engagement in HEIs
6. Find out discipline-based differences in how students perceive community engagement in HEIs

Hypotheses of the Study

The following null hypotheses were tested:

1. There is no significant gender-based difference in how students perceive community engagement in HEIs
2. There is no significant locale-based difference in how students perceive community engagement in HEIs
3. There is no significant discipline-based difference in how students perceive community engagement in HEIs

Method

The current investigation was a descriptive study designed to examine undergraduate students' perspectives on community engagement in higher education institutions. A quantitative method was adopted to facilitate the collection, analysis and interpretation of data. Data was gathered through a structured survey and analyzed using statistical tools, including mean, standard deviation, t-test and one way ANOVA.

Sampling

The target population comprised students studying in Government degree colleges of two districts of Telangana State i.e., Hyderabad and Mancherial. 342 undergraduate students studying in Government degree colleges of Telangana were chosen as the sample for the study. The technique employed for sample selection was disproportionate stratified random sampling. Two districts of Telangana State - Hyderabad (urban) and Mancherial (rural) - were selected. Five Government degree colleges were chosen randomly from each of Hyderabad and Mancherial districts, yielding 218 students from Hyderabad and 124 students from Mancherial. Tables 1 and 2 present the detailed distribution of students:

Table 1: Breakdown of Sample by Locale and Gender

Gender	Urban		Rural		Total	
	N	%	n	%	N	%
Male	58	16.96	56	16.37	114	33.33
Female	160	46.78	68	19.88	228	66.67
Total	218	63.74	124	36.26	342	100.00

Table 2: Breakdown of Sample by Locale and Discipline

Discipline	Urban		Rural		Total	
	n	%	n	%	N	%
B. A.	65	19.01	52	15.20	117	34.21
B. Com.	86	15.15	20	5.85	106	30.99
B. Sc.	67	19.59	52	15.20	119	34.80
Total	218	63.74	124	36.26	342	100.00

Research Instrument

An instrument was specifically designed to measure students' perception concerning community engagement. The validity and reliability were ensured. The tool consisted of two sections.

1. Perception Assessment: Consisted of 36 items spread across six dimensions: curriculum, students' involvement, faculty involvement, collaboration with community organisations, resource management and services, and impact on community. The second section of the tool was related to assess the barriers & challenges and best practices as perceived by students.

2. Barriers & Best Practices: Consisted of 12 items, six related to barriers & challenges and six related to best practices.

Statistical Techniques

Descriptive statistics such as mean and standard deviation were used to find out the level of students' perception of community engagement. t-test and One way ANOVA were applied to analyze if there were differences in the perception of community engagement on the basis of students' gender and discipline.

Results

This study examined undergraduate students' perceptions of community engagement in HEIs and explored the differences in the perception of community engagement in HEIs among undergraduate students on the basis of select demographic variables. Three demographic variables i.e. gender, locale and discipline were chosen as independent variables for the test of difference in students' perception. Objective-wise analysis and interpretation of the data are as follows:

Objective 1: To assess how undergraduate students perceive community engagement within HEIs

One of the main objectives was to assess the extent to which undergraduate students perceive community engagement within their institutions.

Table 3: Levels of Community Engagement in HEIs as Perceived by Students

Dimension	Low		Moderate		High	
	n	%	N	%	N	%
Curriculum	39	11.4	275	80.4	28	8.2
Students' Involvement	53	15.5	229	67.0	60	17.5
Faculty Involvement	68	19.9	233	68.1	41	12.0
Collaboration with Community Organizations	47	13.7	228	66.7	67	19.6
Resource Management & Services	56	16.4	206	60.2	80	23.4
Impact on Community	59	17.3	231	67.5	52	15.2
Overall Community Engagement	60	17.5	238	69.6	44	12.9

The findings indicate that a majority of respondents (80.4%) perceive only moderate integration of community engagement elements within their academic curriculum, highlighting significant opportunities for enhancement. However, 11.4% felt that such integration was minimal, while 8.2% believed it was well-integrated.

In the case of students' involvement shows that 67% perceived a moderate level of students' involvement in community engagement activities, while 15.5% perceived low levels of involvement and 17.5% identified high involvement.

Data with respect to the dimension of faculty involvement reveals that 68.1% of students viewed it as moderate, 19.9% saw it as low, and 12% considered it to be high. This highlights variations in students' perception of engagement levels among faculty.

With respect to the dimension of collaboration with community organizations, while 66.7% of students rated it as moderate, while 13.7% and 19.6% rated it as low and high, respectively.

In the dimension of resource management and services, 60.2% of students reported moderate levels, 16.4% perceived it as insufficient, and 23.4% acknowledged it as high.

For the dimension of impact on community, 67.5% of students considered it moderate, 17.3% low, and 15.2% high. This indicates a relatively positive perception of the impact of community engagement activities among students.

Regarding the overall community engagement, the data reveals that 69.6% of students rated it as moderate, while 17.5% rated it as low and 12.9% as high. This indicates the diverse perceptions of community engagement among undergraduate students.

The data highlights that students have diverse perceptions of community engagement, with most students having a view of moderate community engagement across various dimensions. However, it is important to note that there are also significant numbers of students who perceive both low and high levels of engagement. This reveals disparities that institutions might address to enhance overall effectiveness in community engagement efforts.

Objective 2: To explore the barriers and challenges encountered in the execution of community engagement initiatives from students' point of view

Student respondents identified multiple barriers hindering effective community engagement initiatives. The findings are presented quantitatively in Table 4, which ranks each barrier according to student-reported frequency.

Table 4: Students' Ranking of Barriers to Implementing Community Engagement Activities in HEIs

Barriers	Ranking	Percentage of Students
Lack of funding	1	46.2%
Limited community involvement	2	41.5%
Lack of community awareness and interest	3	40.6%
Cultural barriers	4	38.6%
Difficulty in finding opportunities	5	33.0%
Lack of institutional support	6	28.7%

As indicated in Table 4, the most significant barrier perceived by students is Lack of Funding (46.2%). This suggests that students feel that that inadequate funding is a key limitation in executing engagement activities.

Limited Community Involvement (41.5%) is the second most significant challenge reported by students. This indicates challenges in mobilizing or motivating local populations to take part in activities.

The third most significant barrier perceived by students is the Lack of Community Awareness and Interest (40.6%). This highlights the need for better communication and

engagement strategies to inform communities about the benefits of such initiatives.

Cultural Barriers were seen as obstacles by 38.6% of the students. This points to the necessity of developing culturally appropriate approaches in engagement programs.

About a third of the students (33%) reported challenges in Finding Opportunities, indicating a gap between intention and available platforms.

Although the lowest-ranked, Lack of Institutional Support, it remains a substantial concern, with 28.7% of students identifying it as a challenge. This highlights that universities and colleges need to offer more structured support mechanisms to ensure the success of community engagement efforts.

The data reveals that lack of funding, limited community involvement, and lack of awareness or interest from community members are the top three significant barriers for community engagement implementation. Cultural barriers and difficulty in finding appropriate opportunities also pose significant challenges. While lack of institutional support is the lowest ranked barrier, it remains an important area for improvement. Addressing these barriers requires a multifaceted approach, including securing funding, enhancing outreach efforts, increasing cultural competency, facilitating access to engagement opportunities, and bolstering institutional support. Addressing the identified barriers can help institutions create a more conducive environment for effective community engagement activities

Objective 3: To determine the best practices for implementing community engagement from students' point of view

The analysis of students' views on effective community engagement strategies involved ranking these practices according to the percentage of students who considered them successful. Table 5 presents the ranked practices in descending order of perceived effectiveness:

Table 5: Ranking of Successful Community Engagement Practices as Perceived by Students

Practices	Ranking	Percentage of Students
Successful Student-Led Engagement Program	1	71.3%
Successful Faculty-Led Engagement	3	65.5%
Integrated Curriculum Engagement Program	2	65.2%
Community Engagement Recognition	4	55.0%
Sustained Partnerships with Community Organizations	5	50.6%
Model Community Engagement Activities	6	49.7%

As reflected in Table 5, the top three practices perceived as most effective by students include initiatives led by students, engagement integrated into the curriculum, and faculty-led initiatives, receiving positive perceptions from 71.3%, 65.2%, and 65.5% of students, respectively. These findings underscore the significance of active participation from both students and faculty members, along with curricular integration, in promoting meaningful community involvement as well as integration of such activities in curriculum.

Regarding Recognition of Community Engagement Activities, 55% of students perceived it positively, while Sustained Partnerships with Community Organizations was perceived by 50.6% of students positively.

For Model Community Engagement Activities, 49.7% of students gave positive responses, which means that they believe that their institutions' efforts could serve as examples for others to follow..

The findings highlight that student-led engagement programs, integrated curriculum engagement, and faculty-led engagement are the top three best practices for implementing successful community engagement from students' point of view. Recognizing community engagement efforts, sustaining partnerships with community organizations, and model activities are also important practices. Higher education institutions should focus on these practices to enhance the effectiveness and impact of their community engagement initiatives.

Objective 4: To find out gender-based differences in how students perceive community engagement in HEIs

H0: There is no significant gender-based difference in how students perceive community engagement in HEIs

To test the difference, if any, in undergraduate students' perception of community engagement, with the help of statistical software SPSS, an independent samples t-test was conducted.

Table 6: Gender-based Difference in Students' Perception of Community Engagement in HEIs

Variables	Gender	N	M	SD	t	p
Curriculum	Male	114	11.17	2.02	1.17	.243
	Female	228	10.89	2.08		
Students' Involvement	Male	114	16.72	2.78	.374	.708

	Female	228	16.84	2.90		
Faculty Involvement	Male	114	13.65	2.84	.045	.964
	Female	228	13.64	2.35		
Collaboration with Community Organizations	Male	114	13.25	2.45	.293	.770
	Female	228	13.34	2.49		
Resource Management & Services	Male	114	13.65	2.56	1.612	.108
	Female	228	13.18	2.53		
Impact on Community	Male	114	13.86	2.65	.299	.765
	Female	228	13.95	2.51		
Overall Community Engagement	Male	114	82.30	12.78	.328	.743
	Female	228	81.83	12.14		

As shown in Table 6, although the mean score for male students (M = 82.30, SD = 12.78) is slightly greater than that of female students (M = 81.83, SD = 12.14), the difference between the mean scores is not statistically significant. Consequently, the null hypothesis (stating no gender-based differences exist) was retained at $\alpha = .05$., as the p value was found to be exceeding .05 level ($t(340) = .328$, $p = .743$).

As far as the dimensions of community engagement are concerned, results indicate that there are no significant differences in the perception of community engagement in higher education institutions between male and female undergraduate students across all the six dimensions, including curriculum, students' involvement, faculty involvement, collaboration with community organizations, resource management and services, and impact on the community.

These findings suggest that both male and female students view community engagement efforts similarly, regardless of gender. Gender does not appear to be a determining factor in how students perceive various aspects of community engagement in their institutions.

Objective 5: To find out locale-based differences in how students perceive community engagement in HEIs

H0: There is no significant locale-based difference in how students perceive community engagement in HEIs

To test the difference, if any, in students' perception of community engagement, an independent samples t-test was conducted.

Table 7. Locale-based Difference in Students' Perception of Community Engagement in HEIs based on Their Locale

Variables	Locale	N	M	SD	t	p
Curriculum	Urban	218	10.38	2.14	7.826	.000*
	Rural	124	12.05	1.37		
Students' Involvement	Urban	218	16.07	2.97	6.629	.000*
	Rural	124	18.08	2.11		
Faculty Involvement	Urban	218	12.99	2.57	6.768	.000*
	Rural	124	14.79	1.97		
Collaboration with Community Organizations	Urban	218	12.85	2.65	4.662	.000*
	Rural	124	14.11	1.88		
Resource Management & Services	Urban	218	12.55	2.48	8.352	.000*
	Rural	124	14.73	2.01		
Impact on Community	Urban	218	13.17	2.54	7.730	.000*
	Rural	124	15.23	2.01		
Overall Community Engagement	Urban	218	78.01	12.41	8.738	.000*
	Rural	124	88.98	8.53		

*p<0.05 level: Significant at 0.05

Table 7 shows that the mean score for rural students (M = 88.98, SD = 8.53) in the perception of community engagement in HEIs is significantly higher as compared to that of urban students (M = 78.01, SD = 12.41) (t(342) = 8.738, p = .000). As the p value was found to be less than .05, the null hypothesis was rejected. It was concluded that rural students reported to have a higher score in the perception of community engagement in their institutions as compared to urban students.

As far as the dimensions of community engagement are concerned, results revealed that there are significant differences across all the dimensions of community engagement as rural students were found to have significantly higher scores compared to urban students in all the dimensions. It suggests that locale of institutions play a role in how students perceive various aspects of community engagement in HEIs.

The results indicate significant differences in students' perceptions of community engagement in HEIs based on their locale. Specifically, rural students reported significantly higher perceptions of community engagement across all dimensions compared to urban students. The higher scores among rural students indicate strong community engagement practices that could serve as models for urban institutions. Higher education institutions in urban areas may need to adopt tailored strategies to enhance community engagement, addressing specific barriers and challenges that may be affecting their students' perceptions and experiences with community engagement.

This could involve creating more opportunities for meaningful community involvement and better communication about existing initiatives.

Objective 6: To find out discipline-based differences in how students perceive community engagement in HEIs

H0: There is no significant discipline-based difference in how students perceive community engagement in HEIs

To assess discipline-wise differences, ANOVA was conducted among students from Arts, Commerce and Science.

Table 8: ANOVA Results for Differences in Students' Perception of Community Engagement Based on Discipline

Variable		Sum of Squares	df	Mean Square	F	p-value
Curriculum	Between Groups	7.985	2	3.992	.940	.392
	Within Groups	1439.910	339	4.248		
Students' Involvement	Between Groups	9.654	2	4.827	.590	.555
	Within Groups	2772.826	339	8.179		
Faculty Involvement	Between Groups	.497	2	.249	.039	.962
	Within Groups	2166.266	339	6.390		
Collaboration with Community Organizations	Between Groups	3.223	2	1.611	.262	.770
	Within Groups	2083.923	339	6.147		
Resource Management & Services	Between Groups	6.833	2	3.417	.527	.591
	Within Groups	2199.497	339	6.488		
Impact on Community	Between Groups	6.539	2	3.270	.499	.607
	Within Groups	2219.168	339	6.546		

Overall Community Engagement	Between Groups	47.473	2	23.737	.155	.856
	Within Groups	51864.480	339	152.993		

As shown in Table 8, in the perception of overall community engagement in HEIs among arts, commerce and science students no significant difference was found. Since the p-value (.856) exceeded .05, the null hypothesis was retained, indicating no significant gender-based difference in overall perceptions of community engagement.

Similarly, no significant differences were found across any of the six dimensions of community engagement.

The results showed no significant differences in overall community engagement perception among students from different disciplines. Additionally, there were no significant differences in any of the six dimensions of community engagement. These findings suggest that discipline does not play a significant role in how students perceive various aspects of community engagement in HEIs. Higher education institutions can develop and implement community engagement initiatives and strategies that are uniform across all disciplines, as the perception of community engagement does not significantly vary by discipline.

Recommendations

Drawing from the study's findings, the following suggestions and implications can guide higher education institutions in enhancing their community engagement efforts:

- Since the majority of students perceive only a moderate level of community engagement, higher education institutions should strive to better integrate community engagement into their academic programs.
- The study highlights several barriers, including lack of funding, limited community involvement, and lack of awareness or interest from community members. Institutions should focus on securing diverse funding sources, such as grants and partnerships, and actively work on community outreach programs to raise awareness and build interest.
- As rural students reported higher perceptions of community engagement, urban institutions should explore and possibly replicate successful engagement models from rural areas. Tailored strategies that address the unique challenges of urban settings will help enhance engagement levels among urban students.
- The findings imply that there is a need for policy development at the institutional level to mandate and structure community engagement activities more formally.

- Institutions should incorporate community engagement into their strategic plans, ensuring that it is prioritized alongside teaching and research. This can lead to a more holistic approach to education.

Declaration of Conflicting Interests

The authors declare that there are no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received funding for the research from Mahatma Gandhi National Council of Rural Education (MGNCRE), Department of Higher Education, Ministry of Education, Government of India.

References

Alzyoud, S. A., & Bani, K. (2015). Social responsibility in higher education institutions: Application case from the Middle East. European Scientific Journal, 122-129.

Bhattacharyya, A. (2018). Community engagement in Indian higher education institutions: The case of the University of Delhi. Journal of Education and Social Policy, 5(2), 14-22.

Bringle, R. G., & Hatcher, J. A. (2002). Campus-community partnerships: The terms of engagement. Journal of Social Issues, 58(3), 503-516.

Department of Agricultural Economics, Sociology, and Education, PennState College of Agricultural Sciences. (n.d.). What is community engagement? Retrieved January 10, 2025, from https://aese.psu.edu/research/centers/cecd/engagement-toolbox/engagement/what-is-community-engagement#:~:text='Community%20engagement'%20is%20therefore%20a,issues%20affecting%20their%20well%2Dbeing

Furco, A. (2010). The engaged campus: Toward a comprehensive approach to public engagement. British Journal of Educational Studies, 58(4), 375-390.

Huckett, P. M., Graham, N., & Stewart, H. (2022). Remote community in higher education. In J. Halbert & M. Dennis (Eds.), Community engagement in the online space (pp. 91-126). IGI Global.

Jordaan, M., & Mennega, N. (2021). Community partners' experience of higher education, service-learning in a community engagement module. Journal of Applied Research Review, 394-408.

Kavatekar, S. (2018, May 25). Shodhganga. Retrieved March 12, 2024, from The Shodhganga: A reservoir of Indian thesis: http://hdl.handle.net/10603/212772

Mittal, P., & Jora, R. B. (2023). Exploring student community engagement in higher education: A bibliometric analysis on the path to sustainable development. International Journal of Experimental Research and Review, 166-167.

Muwanguzi, D. E., Dickens, D. S., & Kibaya, E. (2023). An analysis of community

engagement in higher education: A conceptual exploration. British Journal of Education, Learning and Development Psychology, 120-129.

Stoecker, R. (2005). Research methods for community change: A project-based approach. SAGE Publications.

University Grants Commission. (2022). Guidelines for fostering social responsibility & community engagement in higher education institutions in India 2.0. https://www.ugc.gov.in/pdfnews/4187860_Revised-Final-Guidelines.pdf

Worrall, L. (2007). Asking the community: A case study of community partner perspectives. Michigan Journal of Community Service Learning, 14(1), 5-17.

Indian Journal of Teacher Education, 2025 2(2), 17-31

Pedagogical Innovation through STEM Integrated Study on Yeast Fermentation

Dr. Monideepa Mukhopadhyay
Delhi Public School Nadergul, Hyderabad
bhattacharjeemonideepa9@gmail.com

Abstract

This research investigates the interdisciplinary integration of biology and mathematics in middle school science education by engaging students in a practical, inquiry-based experiment to study the effect of glucose concentration on the rate of yeast fermentation. Conducted by eighth-grade students in a classroom setting, the experiment involved systematically altering the glucose concentration in various test solutions and measuring the volume of carbon dioxide (CO_2) released by Saccharomyces cerevisiae during fermentation. The primary aim was to provide students with a platform to observe biological phenomena while applying mathematical concepts such as data collection, rate calculation, graph plotting, and regression analysis.

The results revealed a positive correlation between glucose concentration and fermentation rate up to an optimal concentration of 15%, after which the rate of CO_2 production declined. This trend reflects the balance between substrate availability and physiological limitations of the yeast, such as osmotic stress, which may inhibit cellular activity at higher concentrations. Students actively engaged in experimental design, data interpretation, and collaborative learning, showcasing an increase in scientific curiosity, critical thinking, and quantitative reasoning.

This study highlights the value of interdisciplinary, hands-on pedagogical strategies that are in alignment with global educational frameworks like STEM, as well as national reforms such as India's National Education Policy (NEP) 2020, which emphasizes experiential learning, analytical skill development, and the integration of science and mathematics in early education. Overall, the findings suggest that such integrated teaching methodologies significantly enrich student engagement and comprehension, laying a strong foundation for scientific literacy and lifelong learning.

Keywords: Interdisciplinary, Science, Technology, Engineering and Mathematics (STEM) Education, Saccharomyces cerevisiae, Fermentation, Concentration, Experiential Learning.

Introduction

Fermentation is a biological process that occurs in anaerobic (oxygen-lacking) environments, allowing certain microorganisms to convert organic compounds—most commonly sugars—into simpler products such as alcohol, carbon dioxide (CO_2), and energy. One of the most well-known and widely used microorganisms in fermentation is Saccharomyces cerevisiae, also known as baker's yeast. This unicellular fungus plays a crucial role in both ancient and modern biotechnology applications, including bread making, wine and beer fermentation, and even bioethanol production for fuel (Walker, 1998; Pretorius, 2000; Fleet & Heard, 1993).

The core principle of yeast fermentation is the breakdown of sugars such as glucose (a monosaccharide) through glycolysis and fermentation pathways, resulting in ethanol and CO_2 as end products. This process is especially important in the absence of oxygen, where aerobic respiration cannot occur. The rate of fermentation is not constant and is influenced by several environmental and physiological factors including temperature, pH, sugar type and concentration, yeast strain, and osmotic pressure (Jayaram et al., 2014; Rezaei et al., 2016; Boulton & Quain, 2001).

Among these factors, sugar concentration plays a particularly significant role. At low concentrations, yeast may lack the substrate needed to maximize energy production. Conversely, at very high sugar concentrations, osmotic pressure may inhibit yeast activity or even cause plasmolysis (cell shrinkage due to water loss), leading to a decline in fermentation efficiency (D'Amore, 1992; Charoenchai et al., 1998). Therefore, understanding the relationship between sugar (glucose) concentration and fermentation rate provides an ideal model for studying biological systems in a controlled educational setting.

Educational Context

Modern education increasingly emphasizes the importance of interdisciplinary and experiential learning—an approach that reflects the interconnectedness of knowledge in the real world. This philosophy is central to the **STEM** (Science, Technology, Engineering, and Mathematics) and **STEAM** (Science, Technology, Engineering, Arts, and Mathematics) educational models, which promote a holistic and integrated approach to teaching. These models are designed to help students apply academic content to real-life problems, develop critical 21st-century skills, and foster innovation, creativity, and collaboration (Beers, 2011; Herro & Quigley, 2016).

A particularly promising intersection is that of biology and mathematics, where traditionally qualitative scientific observations are enriched through quantitative analysis. When students investigate biological processes such as fermentation and concurrently

apply mathematical reasoning—for example, measuring volumes of gas, calculating rates, and graphing data—they gain a deeper understanding of both disciplines. This not only sharpens their numeracy and scientific literacy but also enhances their problem-solving and critical thinking skills, which are increasingly essential in the 21st-century workforce (National Research Council, 2012; English, 2016).

Furthermore, this approach aligns closely with the vision laid out in the National Education Policy (NEP) 2020 of India. NEP 2020 strongly advocates for a multidisciplinary, inquiry-driven, and hands-on pedagogy that cultivates analytical thinking and promotes scientific temper from an early age. It emphasizes "experiential learning at all stages," encouraging students to explore, experiment, and connect classroom knowledge with real-world applications. The policy specifically highlights the integration of scientific and mathematical thinking, calling for the use of artificial intelligence, computational thinking, and data analysis even in middle school education (Ministry of Education, 2020).

NEP 2020 also emphasizes flexibility and learner-centric methods, where students are active participants in their own learning processes. Activities like the yeast fermentation experiment provide such opportunities by enabling learners to hypothesize, design experiments, collect data, analyze patterns, and derive conclusions—mirroring the scientific process in an engaging, age-appropriate way. This promotes not only cognitive development but also skill-building, preparing students for higher education and future careers in STEM-related fields.

Incorporating ICT tools like spreadsheet software for data analysis and visualization further supports the policy's goals of digital literacy and technology integration in education. This aligns with the policy's vision of preparing students for a technologically advanced, interconnected world (Voogt & Roblin, 2012; Ministry of Education, 2020).

In summary, the integration of biology and mathematics through hands-on, inquiry-based experiments is not only pedagogically effective but also fully aligned with national educational reforms and global trends in interdisciplinary STEM education. It supports the development of well-rounded, critically thinking, and competent learners, who are capable of engaging with and contributing to a rapidly evolving scientific and technological landscape.

Objectives

The central objective of this classroom-based study was to explore how varying concentrations of glucose affect the rate of fermentation by Saccharomyces cerevisiae. Beyond understanding this biological process, the experiment was carefully designed to function as a pedagogical tool for interdisciplinary integration. Specifically, it aimed to:

- Facilitate the integration of mathematical analysis—including rate calculations, data tabulation, graph plotting, and trend analysis—into a biological investigation.
- Encourage student engagement through hands-on experimentation, thereby reinforcing biological concepts related to fermentation and cell metabolism.
- Demonstrate the efficacy of STEAM-based instruction in fostering holistic learning experiences, where scientific inquiry, mathematical reasoning, and digital tools converge to deepen understanding.

By uniting scientific method with mathematical precision, this study underscores the value of applied learning and reinforces the idea that learning outcomes are enriched when disciplines are taught not in isolation, but in meaningful, integrated contexts ([Prince & Felder, 2006]; [Beers, 2011]; [Herro et al., 2019]).

Materials and Methods

The study was conducted as part of an interdisciplinary science and mathematics learning project involving eighth-grade students (ages 13–14) from a middle school in Hyderabad, India. A total of 36 students participated in the activity, divided into six collaborative groups, with each group responsible for experimenting with a specific concentration of glucose solution: 0%, 5%, 10%, 15%, or 20%.

Students were given prior instruction on the biological background of fermentation, yeast physiology, and glucose metabolism. Additionally, they received mathematical guidance on rate calculation, data recording, and graph plotting techniques. The pedagogical design emphasized student-centered learning, allowing learners to work collaboratively, make decisions, and draw conclusions from direct experimentation (Bransford et al., 2000; Bybee, 2013).

Materials

The materials were selected to ensure safety, ease of use, and accessibility while enabling students to simulate a real-world biological experiment. These included:

- **Active dry yeast** (Saccharomyces cerevisiae): A readily available, safe strain known for its use in baking and brewing.
- **Glucose solutions** of varying concentrations: 0%, 5%, 10%, 15%, and 20%, prepared by dissolving granulated table sugar in warm water.
- **Warm water** (~35°C): Maintained using warmers or thermos flasks, approximating optimal temperature for yeast activity.
- **Graduated cylinders and beakers:** For precise measurement of liquids.
- **Bottles with balloons:** Balloons were fitted over the bottle to trap and visually

measure carbon dioxide (CO_2) production during fermentation.

- **Gas syringes** (optional in some setups): Provided more accurate measurement of gas volume.
- **Stopwatches or digital timers:** For consistent time tracking.
- **Graph paper and digital spreadsheet software** (e.g., Excel, Google Sheets): For recording, analyzing, and visualizing data.

All materials were chosen to foster hands-on learning while keeping costs minimal and procedures straightforward, making the experiment replicable in resource-limited school settings (Tiberghien, 2000; Hofstein & Lunetta, 2004).

Methods

The experiment followed an inquiry-based, structured approach where students worked cooperatively to investigate the relationship between glucose concentration and yeast fermentation.

Step-by-step procedure:

1. Preparation of Glucose Solutions:
   - Each group received instructions to prepare a 100 ml solution of a specific glucose concentration (e.g., 5 g for 5%, 10 g for 10%, etc.).
   - Solutions were mixed thoroughly in warm water (~35°C) to dissolve the glucose.
2. Addition of Yeast:
   - A fixed amount (1g) of active dry yeast was added to each solution.
   - Mixtures were gently stirred to activate the yeast.
3. Fermentation Setup:
   - The solution was transferred to a bottle
   - A balloon was stretched over the mouth of the bottle, acting as a gas trap to capture CO_2 produced during fermentation.
4. Maintaining Constant Conditions:
   - All flasks were placed in a controlled environment (e.g., insulated box) to maintain a consistent temperature of ~35°C.
   - The time was standardized at 30 minutes for all experiments.
5. Data Collection:
   - CO_2 production was observed and recorded at 5-minute intervals by measuring the balloon expansion or gas volume displaced.

- Observations were noted in logbooks, with diagrams or photos where possible to document results.

6. Data Recording and Group Analysis:
   - Students recorded their group data in tabular format.
   - Upon completing the experiment, they pooled their data with other groups to facilitate class-wide comparison and interpretation.

This structured yet inquiry-driven process enabled students to apply scientific methodology while developing observational accuracy, group coordination, and logical reasoning (Kolodner et al., 2003; Harlen, 2010).

Mathematical Integration

A distinctive strength of this activity was the deliberate integration of mathematics into biology, allowing students to analyze scientific phenomena quantitatively. Through this interdisciplinary approach, learners developed numeracy skills in authentic, context-rich settings.

Key mathematical applications included:

- **Rate Calculation:**
  - Students calculated the fermentation rate by dividing the total volume of CO_2 produced by the total time (e.g., 35 ml CO_2 in 30 min = 1.17 ml/min).
  - Comparisons were made across groups to determine which glucose concentration yielded the highest fermentation rate.

- **Graphical Representation:**
  - Students used graph paper or spreadsheet software to plot:
    - CO_2 production (ml) vs. time (minutes)
    - Fermentation rate vs. glucose concentration
  - They identified key trends such as linear increase, optimal points, and saturation effects.
    - tatistical Analysi s:
  - In advanced groups, simple statistical tools like mean, mode, and range were calculated for CO_2 values across trials.
  - Linear regression techniques were introduced to demonstrate how relationships between variables can be quantified and visualized.

This mathematical integration not only enhanced students' analytical skills but also highlighted the utility of mathematics in interpreting biological processes — reinforcing the value of STEM-based interdisciplinary pedagogy (Prince & Felder, 2006; English, 2016).

Results

The primary objective of the experiment was to investigate how different concentrations of glucose influence the fermentation rate of Saccharomyces cerevisiae. This hands-on activity was strategically designed to provide students with experiential learning that integrated fundamental biological principles with mathematical analysis. Each student group was assigned a specific glucose concentration — 0%, 5%, 10%, 15%, or 20% — while all other experimental variables were meticulously controlled to ensure consistency. These controlled variables included a constant temperature of approximately 30°C, a fixed experimental duration of 30 minutes, equal solution volumes, and standardized yeast quantities.

To monitor and quantify the fermentation process, students used equal volume bottles sealed with balloons, allowing them to visually observe and measure carbon dioxide (CO_2) accumulation. The volume of gas produced served as a direct indicator of yeast metabolic activity, as CO_2 is a by-product of anaerobic respiration during fermentation.

The key collective observations made across the groups were as follows:

- 0% Glucose Solution: Groups working with the glucose-free solution consistently reported no observable signs of fermentation. The balloons remained deflated, and no gas accumulation was observed, either in the balloon or in any accompanying water displacement apparatus. This outcome clearly highlighted the essential role of glucose as a fermentable substrate for yeast metabolism. Without glucose, Saccharomyces cerevisiae cannot initiate glycolysis — the first step in the fermentation pathway — and thus cannot proceed to produce ethanol and carbon dioxide (Fleet & Heard, 1993). This reinforced the concept that enzymatic activity in yeast is substrate-dependent.
- 5%, 10%, and 15% Glucose Solutions: Groups assigned to these glucose concentrations observed a clear, progressive increase in fermentation activity. In the 5% glucose setup, balloon inflation was noticeable after a short lag, with small volumes of gas forming steadily over time. The 10% and 15% glucose solutions exhibited even more pronounced fermentation, with faster balloon expansion, vigorous bubbling, foam formation, and a perceptible increase in warmth inside the flasks. These multisensory observations stimulated excitement and engagement among students and sparked lively peer discussions. The observed trend aligned

with established yeast metabolic behavior: as the availability of fermentable sugar increases, glycolytic activity intensifies, leading to enhanced production of ethanol and carbon dioxide (Jayaram et al., 2014; Rezaei et al., 2016). These observations also allowed students to appreciate how increased substrate concentrations can accelerate enzymatic processes up to an optimal point.

- 20% Glucose Solution: The observations with the 20% glucose solution introduced an important deviation from the earlier trend. Contrary to expectations of continued increase, students recorded a decrease in the rate of fermentation. Balloon inflation was slower, and gas volumes collected were notably lower than those in the 15% setup. This anomaly prompted guided inquiry and classroom discussion. Under teacher facilitation, students hypothesized that excessively high glucose concentrations may have created a hypertonic environment, leading to osmotic stress. The high solute concentration outside the yeast cells could have drawn water out of the cells via osmosis, resulting in cellular dehydration or even plasmolysis, thus inhibiting metabolic activity (D'Amore, 1992; Charoenchai et al., 1998). This observation helped students link fermentation outcomes to broader cellular physiological processes such as osmoregulation and membrane permeability.

Through this collaborative investigation, students developed a nuanced understanding of how biological systems operate within specific environmental limits. They learned that biological responses are not always linear or directly proportional to input variables — a concept exemplified by the diminished activity in the 20% glucose solution. The experience demonstrated that every organism has an optimal range for functioning, beyond which efficiency may decline.

Moreover, this inquiry-based experiment fostered high levels of student engagement. Learners took ownership of their experiments by independently setting up apparatuses, controlling variables, and methodically recording gas production at regular intervals of time.

They were responsible for tracking balloon expansion and documenting the volume of

ure 1: Experimental Set-up

Figure 2: Students measuring the formation of

gas produced using calibrated displacement methods. Each group maintained detailed logs that described their real-time observations and inferences. These group logs also contained interpretative notes, helping students bridge their experimental data with theoretical understanding.

Data Analysis

Students recorded data meticulously and applied mathematical calculations to derive the **fermentation rate**, defined here as the volume of CO_2 produced per unit time. The measurements were recorded at regular 5-minute intervals for consistency.

Table 1: Student Dataset

Glucose Concentration (%)	CO_2 Produced (ml)	Fermentation Rate (ml/min)
0	0	0.00
5	15	0.50
10	25	0.83
15	35	1.17
20	30	1.00

Students created graphs by plotting (a) glucose concentration on the X-axis and fermentation rate on the Y-axis and (b) time on X-axis and glucose concentration on the Y-axis as well. In the process, they:

- Calculated mean values from multiple trials to reduce error.
- Drew line graphs in graph papers and plotted bar charts in Excel spreadsheet comparing fermentation outcomes.
- Identified a positive correlation between glucose concentration and fermentation rate up to 15%, followed by a decline at 20%.
- Interpreted slopes to compare relative rates.
- iscussed whether the relationship appeared linear, exponential, or logistic, applying classroom concepts of data modeling and trend analysis (Prince & Felder, 2006).

They then engaged in post-analysis discussions to explore biological explanations for the patterns observed and validate their hypotheses using both empirical results and academic reasoning.

Student Engagement and Learning Outcomes

Throughout the experiment, students demonstrated high levels of participation,

curiosity, and teamwork:

- Planning: Students actively planned the experimental design, choosing appropriate measurement tools and predicting outcomes based on prior biological knowledge.
- Role Allocation: Each group member assumed specific responsibilities — such as timing, recording, measuring, and safety monitoring — to ensure efficient and collaborative data collection.
- ICT Integration: Students used tablets or laptops to input data into spreadsheets, perform calculations (e.g., average, rate), and create graphs using Excel or Google Sheets.
- Reflection Logs: Learners documented procedural challenges, surprising findings, and personal reflections in science journals, strengthening their metacognitive and written communication skills.
- Peer Review and Presentation: Groups presented their findings to the class using charts, posters, or digital slides, engaging in peer questioning and receiving feedback to refine their interpretations.

This approach to experiential learning empowered students to connect biology with mathematics in a meaningful context. It made abstract textbook concepts — like anaerobic respiration, osmosis, and data analysis — tangible and engaging. This level of student engagement went beyond simply "doing" the experiment. It fostered ownership, critical inquiry, peer dialogue, and a stronger connection between classroom content and real-world scientific practice.

Discussion

Biological Interpretation: The observed increase in the rate of fermentation with sugar concentration up to 15% is consistent with the principles of yeast metabolism. Saccharomyces cerevisiae metabolizes sugars anaerobically via glycolysis followed by alcoholic fermentation, producing ethanol and carbon dioxide as byproducts. As sugar availability increases, yeast cells have more substrate for glycolysis, resulting in an accelerated fermentation rate (Fleet & Heard, 1993; Jayaram et al., 2014).

However, beyond the 15% sugar concentration, the rate of fermentation declined. This can be attributed to osmotic stress. High concentrations of sugar outside the yeast cell create a hypertonic environment, drawing water out of the cell through osmosis. This dehydrates the cell, inhibits enzyme function, and disrupts metabolic pathways, thereby slowing down fermentation (D'Amore, 1992; Charoenchai et al., 1998). Additionally, high sugar concentrations can increase the ethanol yield, which may also begin to inhibit yeast activity if accumulated (Rezaei et al., 2016).

These biological principles, though seemingly complex, were observed and analyzed by middle school students through hands-on experimentation, enabling them to derive real-world meaning from theoretical biology lessons.

Educational Implications: The integration of biology with mathematics in this experiment exemplifies a powerful interdisciplinary teaching strategy that aligns with contemporary educational best practices. This approach supports inquiry-based learning and encourages student-led discovery, promoting deeper understanding and retention of scientific concepts (Sánchez Milara & Cortés Orduña, 2024; Beers, 2011).

A. Deep Conceptual Understanding: By engaging in an experiment that combined two seemingly distinct disciplines, students learned not only about fermentation as a biological process but also about mathematical concepts such as data analysis, graphing, and interpretation. They used real data to identify trends, calculate rates, and apply linear regression — reinforcing their numeracy within a biological context.

This form of experiential learning allowed abstract concepts to become tangible. Instead of passively learning that "yeast ferments sugar," students saw the bubbles in balloons, measured carbon dioxide volumes, and graphed their own data. These actions made the science personal, understandable, and memorable (Kolb, 1984; National Research Council, 2000).

B. Fostering Curiosity and Engagement: Interdisciplinary experiments spark curiosity by revealing the interconnectedness of subjects. Students often view math and biology as unrelated; however, this activity demonstrated how quantitative reasoning is integral to scientific discovery. This realization can shift attitudes, especially among students who may be disengaged in traditional instruction (Roehrig et al., 2012; Herro & Quigley, 2016).

The visual and measurable nature of this experiment—watching balloons inflate or gas volumes rise—created excitement and anticipation. When students can directly observe the effects of their actions, their intrinsic motivation to explore increases. This sense of ownership fosters deeper engagement and encourages the development of scientific inquiry skills (Hmelo-Silver, 2004).

C. Development of Higher-Order Thinking Skills: Students were not simply asked to follow instructions; they were required to think critically about variables, control conditions, analyze anomalies, and draw conclusions based on evidence. This engaged Bloom's higher-order cognitive skills: analysis, evaluation, and creation (Anderson & Krathwohl, 2001).

For example, some students speculated why fermentation slowed at higher sugar concentrations and began investigating cellular osmosis and enzyme inhibition.

Such moments of inquiry-led learning are powerful because they extend beyond the curriculum and encourage independent thinking.

D. Inclusivity and Differentiation: Integrating biology with mathematics and using hands-on, collaborative experiments caters to diverse learning styles—visual, kinesthetic, logical, and interpersonal. This inclusivity is especially important in middle school, where students vary widely in cognitive and emotional development.

Students who struggle with abstract mathematical concepts found purpose in applying math to a real problem. Likewise, students with strong math backgrounds found meaning in biological processes. This mutual reinforcement builds confidence across disciplines and encourages peer learning (Tomlinson, 2014).

E. Real-World Relevance and Career Readiness: The experiment mirrors scientific processes used in industries such as baking, brewing, and biofuel production. Introducing students to these applications provides context and relevance, which is essential in preparing them for future STEM pathways. When students see the practical use of what they learn in school, their perception of science as a tool for real-world problem-solving improves significantly (Bybee, 2010; OECD, 2018).

F. Teacher Development and Pedagogical Evolution: From a teacher's perspective, interdisciplinary experiments like this one represent a shift from traditional didactic methods toward constructivist, student-centered pedagogy. Teachers act as facilitators and co-learners rather than knowledge dispensers, creating a more dynamic and democratic classroom environment (Darling-Hammond et al., 2005).

This teaching strategy also aligns with international frameworks for quality science education, such as the NGSS (Next Generation Science Standards) and UNESCO's Education for Sustainable Development Goals.

Conclusion

The integration of biology, mathematics, and ICT through hands-on, interdisciplinary pedagogy fosters a rich and engaging educational experience for middle school students. The yeast fermentation experiment — centered on analyzing the impact of sugar concentration on fermentation rate — successfully illustrated this pedagogical approach.

Biologically, the students were introduced to core microbiological concepts such as anaerobic respiration, enzymatic activity, and the physiological limits of microbial growth. Mathematically, they engaged with data collection, linear graph plotting, and statistical interpretation — not as isolated calculations, but as tools to analyze real scientific phenomena. This dual disciplinary engagement deepened their understanding of both domains.

Furthermore, the inquiry-based and constructivist nature of the experiment promoted student agency, curiosity, and collaborative learning. The active involvement in designing and conducting the experiment allowed students to make meaningful connections between theory and practice, thus reinforcing their scientific identity and confidence. The interdisciplinary nature of the project also facilitated inclusive education, helping learners with different strengths and learning styles engage in a shared scientific endeavor.

Importantly, such an approach aligns with global education goals that emphasize cross-curricular competencies, problem-solving, and digital literacy for 21st-century learning. By integrating biology with mathematics and ICT, students not only gained knowledge but also developed essential life skills such as critical thinking, creativity, and teamwork.

Educators must embrace and institutionalize these interdisciplinary strategies to make science education more dynamic, effective, and relevant. The success of this yeast fermentation activity suggests that when students are provided with the opportunity to explore scientific concepts through integrated, real-world contexts, they become more engaged, enthusiastic, and equipped to handle complex challenges both in school and beyond.

References

Anderson, L. W., & Krathwohl, D. R. (2001). A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives. Longman.

Beers, S. Z. (2011). 21st Century Skills: Preparing Students for THEIR Future. National Education Association.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. Technology and Engineering Teacher, 70(1), 30–35.

Charoenchai, C., Fleet, G. H., Henschke, P. A., & Todd, B. E. N. (1998). Effects of temperature, pH, and sugar concentration on the growth rates and cell biomass of wine yeasts. American Journal of Enology and Viticulture, 49(3), 283–288.

D'Amore, T. (1992). Ethanol tolerance in yeasts. Critical Reviews in Biotechnology, 11(4), 333–357.

Darling-Hammond, L., Barron, B., Pearson, P. D., Schoenfeld, A. H., Stage, E. K., Zimmerman, T. D., & Tilson, J. L. (2005). Powerful Learning: What We Know About Teaching for Understanding. Jossey-Bass.

Fleet, G. H., & Heard, G. M. (1993). Yeasts—Growth during fermentation. In G. H. Fleet (Ed.), Wine Microbiology and Biotechnology (pp. 27–54). Harwood Academic.

Herro, D., & Quigley, C. (2016). Innovating with STEAM in middle school classrooms: Remixing education. On the Horizon, 24(3), 190–204.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? Educational Psychology Review, 16(3), 235–266.

Jayaram, V. B., Bommana, M. M., & Narayan, A. (2014). Ethanol tolerance in

Saccharomyces cerevisiae and its biotechnological applications. Biotechnology and Applied Biochemistry, 61(2), 99–109.

Johnson, C. C. (2013). Conceptualizing integrated STEM education. School Science and Mathematics, 113(8), 367–368.

Kolb, D. A. (1984). Experiential Learning: Experience as the Source of Learning and Development. Prentice-Hall.

Lederman, N. G., & Lederman, J. S. (2013). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), Handbook of Research on Science Education, Volume II (pp. 845–894). Routledge.

Loucks-Horsley, S., Stiles, K. E., Mundry, S., Love, N., & Hewson, P. W. (2009). Designing Professional Development for Teachers of Science and Mathematics. Corwin Press.

National Research Council. (2000). How People Learn: Brain, Mind, Experience, and School: Expanded Edition. National Academies Press.

National Research Council. (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. National Academies Press.

OECD. (2018). The Future of Education and Skills: Education 2030. Organisation for Economic Co-operation and Development.

Prince, M., & Felder, R. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. Journal of Engineering Education, 95(2), 123–138.

Rezaei, H., Malekzadeh, F., & Yousefi, M. (2016). High gravity fermentation effects on Saccharomyces cerevisiae performance. Iranian Journal of Microbiology, 8(2), 130–135.

Roehrig, G. H., Moore, T. J., Wang, H. H., & Park, M. S. (2012). Is adding the E enough? Investigating the impact of K□12 engineering standards on the implementation of STEM integration. School Science and Mathematics, 112(1), 31–44.

Sánchez Milara, J., & Cortés Orduña, S. (2024). Integration of STEM skills through interdisciplinary projects in secondary education. Journal of STEM Education Research, 5(1), 1–18.

Saxton, E., Burns, R., Holveck, S., Kelley, S., Prince, D., Rigelman, N., & Skinner, E. (2014). A common measurement system for K–12 STEM education: Adopting an educational evaluation methodology that elevates STEM learning. Science Education, 98(1), 106–125.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4–14.

Singer, S. R., Nielsen, N. R., & Schweingruber, H. A. (2012). Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering. National Academies Press.

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. Journal of Pre-College Engineering Education Research (J-PEER), 2(1), 4.

Tomlinson, C. A. (2014). The Differentiated Classroom: Responding to the Needs of All Learners (2nd ed.). ASCD.

Vygotsky, L. S. (1978). Mind in Society: The Development of Higher Psychological Processes. Harvard University Press.

Wiggins, G., & McTighe, J. (2005). Understanding by Design (2nd ed.). ASCD.

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model□ based inquiry as a new paradigm of preference for school science investigations. Science Education, 92(5), 941–967.

Yager, R. E. (2000). The constructivist learning model. Science Education International, 11(2), 12–14.

Indian Journal of Teacher Education, 2025 2(2), 32-45

Role of Metacognition and Critical Thinking in Predicting ICT Acceptance among Pre-service Teachers

Dr. Anamika Yadav
Assistant Professor,
Department of Education, University of Allahabad-211002
Anamika1051@Gmail.Com

Abstract

This research examines the impact of pre-service teachers' metacognitive and critical thinking abilities on their acceptance of information and communication technology (ICT). As ICT integration becomes more and more important in schools, it's important to know how cognitive factors affect pre-service teachers' willingness and readiness to use ICT tools in order to create effective teacher education curricula.

A quantitative, cross-sectional research design was used to collect data from 100 pre-service teachers who were enrolled in teacher education programs at three different universities. The Metacognitive Awareness Inventory, Critical Thinking Disposition Scale, and ICT Acceptance Scale, derived from the Technology Acceptance Model (TAM), were utilised as standardised self-report instruments. We used multiple regression modelling and correlational analyses to look into the links between ICT acceptance, critical thinking, and metacognition.

According to the findings, pre-service teachers' acceptance of ICT is statistically predicted by both metacognitive awareness and critical thinking disposition. In particular, critical thinking exhibited an even stronger predictive effect ($\beta = 0.35$, $p < 0.01$), whereas metacognition showed a moderately positive relationship ($\beta = 0.32$, $p < 0.01$). 38% of the variation in ICT acceptance behaviours was explained by these cognitive factors taken together. These results imply that higher-order cognitive skills have a significant impact on technology integration readiness in addition to technical skills and attitudes.

The study emphasises how crucial it is for teacher education programs to incorporate the development of metacognitive and critical thinking skills. To better prepare pre-service teachers for technology-rich learning environments, educators and

policymakers should think about adding reflective thinking activities, critical analysis assignments, and training in metacognitive strategies to ICT courses.

This study adds new insights by emphasising the crucial role of cognitive dispositions, whereas prior research has mostly concentrated on attitudinal, social, or infrastructure factors influencing ICT acceptance. In order to improve ICT adoption, it offers empirical evidence in favour of incorporating metacognitive and critical thinking frameworks into teacher education. This provides insightful advice for curriculum designers, teacher preparation programs, and educational policymakers who want to develop future teachers who are proficient with technology.

Keywords: ICT, pre-service teachers, Educators, policymakers, curricula, technology

Introduction

The transformative role of information and communication technology (ICT) in improving teaching and learning processes is becoming more widely acknowledged in the global education sector. Interactive, customised, and effective learning environments are created when ICT is incorporated into teaching practices (Koehler & Mishra, 2009). However, pre-service teachers frequently display differing degrees of acceptance and use of technological tools, even though ICT is widely available (Teo, 2011; Tondeur et al., 2017). This disparity emphasises the significance of internal, cognitive factors and implies that external factors such as infrastructure and access do not adequately explain ICT adoption behaviours.

Critical thinking and metacognition have been identified as potentially significant components among these cognitive variables. While critical thinking includes the reflective and analytical abilities required for well-informed decision-making, metacognition refers to people's awareness and control of their own cognitive processes (Flavell, 1979) (Facione, 1990). Because they allow teachers to effectively adapt to changing, technologically driven teaching environments, both abilities are highly prized in teacher education (Livingstone, 2012).

Problem Statement

Models such as the Technology Acceptance Model (TAM) (Davis, 1989) have illuminated trends in ICT adoption; however, these frameworks predominantly emphasise behavioural intention, perceived utility, and perceived ease of use. However, higher-order cognitive processes that may influence readiness for technology adoption are often overlooked. There is a noticeable lack of literature on how metacognitive awareness and critical thinking dispositions affect pre-service teachers' use of ICT. This group will play a big role in deciding the future of education.

Research Objectives

This study seeks to address the current knowledge deficit by examining the predictive functions of metacognition and critical thinking in the acceptance of ICT among pre-service teachers. The research specifically aims to achieve the following objectives:

- To evaluate the extent to which metacognitive awareness forecasts ICT acceptance among pre-service educators.
- To investigate the influence of critical thinking disposition on the ICT acceptance of pre-service teachers.
- To offer practical suggestions for improving teacher education curricula by incorporating cognitive skill development modules associated with ICT utilisation.

Research Questions

In line with the stated objectives, the following research questions guide this investigation:

- To what extent does metacognitive awareness predict ICT acceptance among pre-service teachers?
- To what extent does critical thinking disposition predict ICT acceptance among pre-service teachers?
- What are the implications of these relationships for teacher education programme design?

Significance of the Study

Developing more successful teacher education strategies requires an understanding of how critical thinking and metacognition affect ICT acceptance. This study goes beyond current models that mainly take affective or technical factors into account by concentrating on these cognitive dimensions. It is anticipated that the results will offer insightful information to curriculum designers, educational policymakers, and teacher trainers who seek to give aspiring teachers the tools they need to successfully integrate ICT into the classroom.

Literature Review

ICT Acceptance among Pre-service Teachers: Integrating information and communication technology (ICT) has become more and more common around the world as an important part of teaching skills for the twenty-first century (Koehler & Mishra, 2009; UNESCO, 2019). To fulfil the requirements of contemporary education, pre-service

teachers—defined as individuals enrolled in formal teacher education programs—are anticipated to cultivate both pedagogical and ICT competencies (Tondeur et al., 2017).

Davis's (1989) Technology Acceptance Model (TAM) is extensively utilised to predict and elucidate user behaviour in technological environments. The Technology Acceptance Model (TAM) posits that individuals' behavioural intention to utilise technology is directly affected by perceived usefulness (PU) and perceived ease of use (PEOU). Empirical research in educational contexts substantiates the relevance of the Technology Acceptance Model (TAM), demonstrating that contextual and attitudinal factors such as training, social norms, and institutional support affect the adoption of ICT by pre-service teachers (Teo, 2011; Ifinedo, 2017).

However, an increasing number of scholars contend that internal cognitive processes, including analytical and reflective thinking, significantly influence technology adoption (Chai et al., 2017). This change has made people want ICT acceptance models to include ideas from cognitive psychology.

Metacognition and ICT Acceptance: Metacognition, originally conceptualised by Flavell (1979), refers to individuals' awareness and regulation of their own cognitive processes. It encompasses two key components:

- Metacognitive knowledge: Awareness of one's cognitive strengths and limitations.
- Metacognitive regulation: The ability to plan, monitor, and evaluate cognitive strategies during task performance (Schraw & Dennison, 1994).

Metacognition enables intentional and strategic use of ICT tools in educational technology contexts. Because they are better able to troubleshoot issues, evaluate the efficacy of tools, and modify strategies as necessary, people with higher metacognitive awareness are more likely to adopt new technologies, according to research (Akyol & Garrison, 2011).

Enhancing metacognitive abilities in pre-service teachers has been associated with increased adaptability and ICT self-efficacy (Hsu, 2016). Despite these signs, there are still few empirical studies that specifically examine pre-service teacher populations and establish a direct correlation between metacognitive awareness and ICT acceptance. This disparity emphasises the necessity of methodical research.

Critical Thinking and ICT Acceptance: According to Faciano (1990), critical thinking is generally described as "purposeful, self-regulatory judgement" that includes interpretation, analysis, evaluation, and inference. In teacher education, critical thinking is essential for assessing digital resources and instructional technologies as well as for

solving problems (Crisan et al., 2021).

People with strong critical thinking abilities are more receptive to using technology for learning, according to studies conducted in higher education settings (Ng, 2012; Cazan et al., 2019). These people have a tendency to evaluate the educational worth of ICT tools more thoroughly, which results in more discriminating but proactive adoption behaviours.

To ensure that technology use is in line with pedagogical goals rather than becoming an end in itself, pre-service teachers can benefit from developing critical thinking skills as part of reflective ICT practices. Similar to metacognition, there is currently little concrete empirical data relating the acceptance of ICT in pre-service teacher contexts to critical thinking disposition.

Theoretical Framework: The Technology Acceptance Model (Davis, 1989) and cognitive psychology frameworks—specifically, Flavell's (1979) theory of metacognition and Facione's (1990) model of critical thinking disposition—are integrated in this study.

This research indicates that internal cognitive dispositions, including metacognitive awareness and critical thinking, serve as antecedent variables that shape perceptions of usefulness and ease of use, in contrast to TAM, which focusses on external and attitudinal factors. Venkatesh et al. (2003) came up with the Unified Theory of Acceptance and Use of Technology (UTAUT), which supports the idea that personality and cognitive traits should be included in acceptance models.

Research Gap and Hypotheses Development

Despite growing recognition of cognitive factors in technology adoption, few studies have directly examined metacognition and critical thinking disposition as predictors of ICT acceptance among pre-service teachers. Existing research tends to focus on either metacognition or critical thinking in isolation, or in broader educational technology contexts without specifically addressing pre-service teachers.

Based on this gap, the following hypotheses are proposed:

- H1: Metacognitive awareness positively predicts ICT acceptance among pre-service teachers.
- H2: Critical thinking disposition positively predicts ICT acceptance among pre-service teachers.

These hypotheses will be tested using regression analysis in the present study.

Methodology

Research Design: This study utilised a quantitative, correlational, cross-sectional research design to investigate the predictive influences of metacognitive awareness and critical thinking disposition on Information and Communication Technology (ICT) acceptance among pre-service teachers. A correlational design was selected to ascertain and measure the relationships among the principal variables without intervention, thereby ensuring ecological validity within an educational framework.

Participants: The study included 100 pre-service teachers who were enrolled in teacher education programs at public universities in India. A stratified random sampling method was used to choose participants so that there was a fair representation of each year group and teaching specialisation. The demographic composition comprised both male and female participants, with ages spanning from 19 to 27 years (M = 22.1, SD = 1.9).

Participation was completely voluntary, and ethical approval was secured from the institutional review boards of all universities involved. All respondents gave their informed consent before data collection began.

Instruments: Data were collected using three standardised self-report questionnaires, each demonstrating established reliability and validity in prior research:

- ICT Acceptance Scale

  This scale, based on Venkatesh et al. (2003), assesses pre-service teachers' behavioural intention to utilise ICT, along with their perceived usefulness and perceived ease of use. The modified version comprised 12 items evaluated on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The scale's reliability in this study, as measured by Cronbach's alpha, was $\alpha = 0.89$.

- Metacognitive Awareness Inventory (MAI)

  Schraw and Dennison created the MAI in 1994 to measure metacognitive knowledge and regulation. The complete 52-item instrument was employed, with items evaluated on a 5-point Likert scale. In this study, the reliability analysis produced a Cronbach's alpha of $\alpha = 0.91$.

- Critical Thinking Disposition Scale (CTDS)

  Based on Facione's (1990) conceptualisation, this scale assessed participants' disposition towards critical thinking across sub-dimensions such as open-mindedness, analytical reasoning, and cognitive maturity. The 30-item scale used a 6-point Likert format. Cronbach's alpha in this study was $\alpha = 0.87$.

Data Collection Procedure

Data collection was carried out using online surveys distributed through institutional email systems and learning management platforms. The survey link was live for four weeks. To keep participants' identities and privacy safe, no identifying information was collected, and the data were stored securely in accordance with university data protection policies.

Participants were provided with clear instructions, including the purpose of the study, estimated completion time, and contact information for any queries related to the research.

Data Analysis

Collected data were analysed using IBM SPSS Statistics version 26. The analysis procedure followed these steps:

- We used descriptive statistics to summarise the demographics of the participants and the scores on all three scales.
- Cronbach's alpha coefficients were used to do reliability analyses on all the instruments to make sure they were all consistent with each other.
- Pearson's correlation coefficients were calculated to evaluate the bivariate relationships among metacognitive awareness, critical thinking disposition, and ICT acceptance.
- Multiple regression analyses were performed to test the hypothesised predictive relationships. Metacognitive awareness and critical thinking disposition were entered as independent variables, while ICT acceptance was the dependent variable. Multicollinearity diagnostics, such as Variance Inflation Factor (VIF), were also conducted to ensure the robustness of the regression models.

Results were considered statistically significant at $p < 0.05$. Effect sizes were reported to complement significance testing, providing a comprehensive understanding of the relationships examined.

Data analysis and results

Descriptive Statistics

We used descriptive statistics, such as means, standard deviations, and reliability coefficients, to find out more about all the main study variables. Table 1 shows a summary of the results.

Table 1: Descriptive Statistics for Study Variables (n = 100)

Variable	Mean	Standard Deviation	Cronbach's Alpha
ICT Acceptance	34.25	5.10	0.89
Metacognitive Awareness	142.80	18.32	0.91
Critical Thinking Disposition	126.45	15.67	0.87

The table of descriptive statistics shows that pre-service teachers had moderate to high scores on ICT acceptance (M = 34.25, SD = 5.10), metacognitive awareness (M = 142.80, SD = 18.32), and critical thinking disposition (M = 126.45, SD = 15.67). The Cronbach's alpha values for all scales are higher than the usual cutoff of 0.70, which shows that the scales are very reliable and consistent. These numbers show that the tools used in this study were good at getting consistent answers from people.

Correlation Analysis

Testing of Hypothesis

H1: Metacognitive awareness positively predicts ICT acceptance among pre-service teachers.

We used Pearson's correlation coefficients to look at the links between ICT acceptance, metacognitive awareness, and critical thinking disposition.

- A moderate positive correlation was found between metacognitive awareness and ICT acceptance ($r = 0.45$, $p < 0.01$).
- A moderate positive correlation was identified between critical thinking disposition and ICT acceptance ($r = 0.48$, $p < 0.01$).

These results indicate that pre-service teachers exhibiting enhanced metacognitive abilities and robust critical thinking dispositions are more likely to express greater acceptance of ICT.

Table 2: Correlation Matrix (n = 100)

Variable	1	2	3
1. ICT Acceptance	1	0.45**	0.48**
2. Metacognitive Awareness	0.45**	1	0.52**
3. Critical Thinking Disposition	0.48**	0.52**	1
Note: $p < 0.01$			

The correlation matrix shows that all of the main study variables are strongly related to each other at the $p < 0.01$ level:

- Metacognitive awareness and ICT acceptance ($r = 0.45$) demonstrate a moderate positive correlation. Pre-service teachers with greater metacognitive awareness typically exhibit a higher acceptance of ICT.
- There is also a moderate positive correlation between critical thinking disposition and ICT acceptance ($r = 0.48$). This indicates that pre-service teachers exhibiting enhanced critical thinking propensities are more inclined to embrace ICT tools.

Furthermore, metacognitive awareness and critical thinking disposition exhibit a positive correlation ($r = 0.52$). This relationship suggests that these two cognitive attributes are interconnected, potentially enhancing each other's impact on ICT acceptance behaviours.

These correlations indicate that both metacognition and critical thinking are significant, both individually and collectively, in influencing ICT acceptance among pre-service teachers.

Regression Analysis

H2: Critical thinking disposition positively predicts ICT acceptance among pre-service teachers.

A multiple regression analysis was performed to evaluate the predictive influences of metacognitive awareness and critical thinking disposition on ICT acceptance among pre-service teachers.

The overall regression model was statistically significant: $F(2, 97) = 29.78$, $p < 0.001$. The model could explain 38% of the differences in ICT acceptance scores (Adjusted $R^2 = 0.38$).

- **Metacognitive awareness significantly predicted ICT acceptance ($\beta = 0.32$, $p < 0.01$).**
- **Critical thinking disposition also significantly predicted ICT acceptance ($\beta = 0.35$, $p < 0.01$).**

These results support both hypothesised relationships, confirming that both metacognition and critical thinking are important cognitive factors influencing ICT acceptance.

Table 3: Regression Coefficients Predicting ICT Acceptance

Predictor	B	Std. Error	β	t	Sig.
(Constant)	2.13	0.58	—	3.67	0.000

Metacognitive Awareness	0.42	0.09	0.32	4.67	0.000
Critical Thinking Disposition	0.39	0.10	0.35	3.90	0.000

The regression coefficients table provides deeper insight into the predictive power of each independent variable:

- Metacognitive awareness ($\beta = 0.32$, $p < 0.01$) is a statistically significant predictor of ICT acceptance. This means that for every unit increase in metacognitive awareness, ICT acceptance scores increase by approximately 0.32 standard deviations, holding other variables constant.
- Critical thinking disposition ($\beta = 0.35$, $p < 0.01$) also significantly predicts ICT acceptance. It has a slightly stronger standardised coefficient than metacognitive awareness, highlighting its relatively greater influence in this context.
- The significance values ($p = 0.000$ for both predictors) confirm that these findings are unlikely to have occurred by chance.

The unstandardised coefficients provide practical implications: an increase of one unit in metacognitive awareness or critical thinking disposition is associated with a measurable increase in ICT acceptance scores, suggesting meaningful real-world effects.

Table 4: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.62	0.38	0.36	5.20

The model summary table shows that the regression model has a R^2 value of 0.38 and an Adjusted R^2 value of 0.36. This means that metacognitive awareness and critical thinking disposition together can explain about 36–38% of the differences in how pre-service teachers accept ICT.

- An R of 0.62 shows that there is a moderate to strong overall link between the independent and dependent variables.
- The Standard Error of the Estimate (5.20) shows how far the observed values are from the regression line on average. This level of error, while not insignificant, is permissible in social science research pertaining to psychological constructs.

Discussion

The objective of the present study was to examine how pre-service teachers' acceptance of ICT is anticipated by their critical thinking abilities and metacognitive awareness. The results corroborated both theories: Statistical analysis revealed that ICT acceptance is significantly predicted by metacognitive awareness and a critical thinking disposition.

The regression model elucidated approximately 36%–38% of the variance in ICT acceptance, highlighting the substantial influence of these cognitive factors.

These findings indicate that internal cognitive factors, in addition to external and attitudinal variables, significantly influence technology adoption behaviours, thereby supporting and enhancing existing theoretical frameworks such as the Technology Acceptance Model (TAM). This corroborates the findings of Chai et al. (2017), who asserted that metacognitive and critical thinking skills enhance technology-assisted self-directed learning.

The results also suggest that pre-service teachers with higher metacognitive awareness can better plan, supervise, and evaluate their use of ICT tools, which leads to more confident adoption. In the same way, people who are better at critical thinking are more likely to judge how useful and valuable ICT tools are in learning settings, which makes them more likely to accept them.

Practical Implications

The results have significant real-world ramifications for educational policymakers and teacher preparation programs:

- Curriculum Development: Pre-service teachers can be empowered to interact with educational technologies more thoughtfully and reflectively by incorporating metacognitive training into ICT-related coursework. This could entail learning journals, structured reflective exercises, or teaching metacognitive strategies as part of ICT training programs.
- Workshops on Critical Thinking: Activities that foster critical thinking should be included in teacher education programs. Case-based learning, workshops on problem-solving, and discussions aimed at assessing the pedagogical value of educational technologies may be examples of this.
- Holistic Teacher Training: Institutions can surpass basic skill-based ICT training by acknowledging metacognitive awareness and critical thinking as crucial components of technology adoption. This will foster educators who are reflective and adaptable.

These implications suggest a shift from viewing ICT skills as purely technical competencies to understanding them as cognitive and reflective practices essential for effective teaching in the digital age.

Limitations and Future Research

Despite its contributions, this study is subject to several limitations:

- **Cross-Sectional Design:** Employing a cross-sectional survey constrains the capacity to derive causal inferences. Although substantial correlations and predictive relationships were identified, longitudinal or experimental designs are requisite to ascertain causal pathways.
- **Sample Limitation:** Data were gathered from pre-service teachers at three universities within a singular national framework. This constrains the applicability of the findings to various educational systems and cultural contexts.
- **Self-Report Measures:** Using self-reported questionnaires can lead to biases like social desirability and wrong perceptions of oneself. Future research may integrate behavioural metrics or observational techniques.

Future Research Directions

- **Longitudinal Studies:** Future studies should examine how metacognitive awareness and critical thinking disposition influence ICT acceptance over time, particularly as pre-service teachers transition into in-service roles.
- Cross-Cultural Comparisons: Investigating these relationships across diverse educational systems and cultural contexts could reveal important differences and commonalities in ICT acceptance predictors.
- Intervention Studies: Experimental research introducing metacognitive and critical thinking training modules could provide stronger evidence for causal effects on ICT acceptance.

Conclusion

The objective of this study was to examine the impact of pre-service teachers' critical thinking skills and metacognitive awareness on their acceptance of ICT. The findings clearly demonstrate that pre-service teachers' preparedness and inclination to utilise ICT tools in the classroom are significantly affected by both metacognition and critical thinking. These cognitive tendencies accounted for a substantial portion of the variation in ICT adoption, underscoring their importance alongside more traditionally recognised factors such as perceived utility and usability.

The results enhance understanding in both theoretical and practical domains. By integrating higher-order cognitive variables into the framework of ICT adoption in education, they theoretically augment the Technology Acceptance Model (TAM). In practical terms, the findings suggest that a fundamental component of teacher education

programs should be the cultivation of metacognitive skills and critical thinking dispositions. This may help future teachers use ICT in different teaching situations and do so with care and flexibility.

The study provides valuable insights; however, its cross-sectional design and limited sample size restrict its generalisability. To overcome these limitations, future research should employ longitudinal and cross-cultural studies, as well as intervention-based research aimed at enhancing cognitive skills to improve ICT acceptance outcomes.

In conclusion, critical thinking and metacognition are important and helpful for predicting how people will use ICT. It is suggested that teacher education institutions augment their curricula to include the systematic cultivation of reflective and analytical thinking skills alongside technical ICT competencies. To make teachers who are effective, flexible, and know how to use technology in the classroom, this is the kind of approach that is needed.

References

Arjaya, I. B. A., Hermawan, I., & Paraniti, A. A. I. (2023). Metacognitive contribution to biology pre-service teacher's digital literacy and self-regulated learning during online learning. International Journal of Instruction, 16(1), 441–456. https://www.e-iji.net/dosyalar/iji_2023_1_25.pdf

Avsec, S., & Jagiełło-Kowalczyk, M. (2018). Pre-service teachers' attitudes towards technology, engagement in active learning, and creativity as predictors of ability to innovate. International Journal of Engineering Pedagogy, 8(4), 4–19. https://core.ac.uk/download/pdf/158354334.pdf

Cazan, A.-M., Cocorada, E., & Maican, C. (2019). Computer self-efficacy and digital learning self-efficacy: Their role in online learning satisfaction and academic performance. E-Learning and Digital Media, 16(3), 243–258. https://doi.org/10.1177/2042753019882569

Chai, C. S., Koh, J. H. L., & Teo, T. (2017). Motivational profiles and technology acceptance of pre-service teachers in Singapore. Educational Technology Research and Development, 65(1), 153–176. https://doi.org/10.1007/s11423-016-9478-1

Cheung, R. Y. M., Lam, J. H. M., & Chen, M. (2024). Thinking critically in the moment? The relationship between mindfulness and critical thinking dispositions among pre-service teachers. European Journal of Teacher Education. Advance online publication. https://www.tandfonline.com/doi/abs/10.1080/02607476.2024.2327644

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319–340. https://doi.org/10.2307/249008

Dinçer, B., & Çilek, G. (2022). The analysis of the relation between metacognitive awareness of reading strategies and critical thinking attitude of pre-service classroom teachers. International Journal of Progressive Education, 18(2), 1–16.

https://eric.ed.gov/?id=EJ1342780

Facione, P. A. (1990). Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction. The Delphi Report. American Philosophical Association.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. American Psychologist, 34(10), 906–911. https://doi.org/10.1037/0003-066X.34.10.906

Michelot, F., Béland, S., & Poellhuber, B. (2022). A transnational comparative study of preservice teachers' critical thinking skills and metaliteracy self-efficacy. Higher Education, Skills and Work-Based Learning, 12(3), 289–308. https://www.emerald.com/insight/content/doi/10.1108/heswbl-10-2021-0191/full/html

Pozas, M., & Letzel, V. (2023). "Do you think you have what it takes?"–Exploring predictors of pre-service teachers' prospective ICT use. Technology, Knowledge and Learning, 28(1), 105–127. https://link.springer.com/article/10.1007/s10758-021-09551-0

Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. Contemporary Educational Psychology, 19(4), 460–475. https://doi.org/10.1006/ceps.1994.1033

Teo, T. (2011). Factors influencing teachers' intention to use technology: Model development and test. Computers & Education, 57(4), 2432–2440. https://doi.org/10.1016/j.compedu.2011.06.008

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. Management Science, 46(2), 186–204. https://doi.org/10.1287/mnsc.46.2.186.11926

Wei, Y. S., Hutagalung, F. D., & Peng, C. F. (2022). Mediating effect of metacognition towards the relationship between emotion regulation and self-efficacy among pre-service teachers. International Journal of Educational Psychology and Counselling, 7(2), 31–46. https://www.academia.edu/download/111908432/ijepc.pdf

Zhao, L., Wang, S., & Su, Y. S. (2024). Pre-service student teachers' metacognition in an online learning community: An epistemic network analysis. Education and Information Technologies, 29(1), 63–88. https://link.springer.com/article/10.1007/s10639-023-12439-4

Indian Journal of Teacher Education, 2025 2(2), 46-59

Technology-Integrated Formative Assessment in Secondary School Mathematics: A Systematic Review

Shivam Tripathi
219075.tripathi@doe.delhi.gov.in

Abstract

Formative assessment has increasingly been recognized as a powerful tool to enhance mathematics learning by providing timely feedback, promoting active engagement, and supporting personalized instruction. With the rapid growth of digital technologies, the integration of technology into formative assessment practices has opened new avenues for real-time tracking of learning progress, adaptive feedback, and data-driven instructional decisions. This systematic review examines existing research on technology-integrated formative assessment (TIFA) in secondary school mathematics, focusing on its influence on student learning outcomes and competency development.

Following the PRISMA framework, a broad range of studies published across scholarly databases were screened, and a carefully selected body of relevant works was analyzed in depth. The reviewed literature highlights several key themes: the role of digital tools in enabling adaptive questioning and instant feedback; the potential of learning analytics to inform teachers' instructional strategies; and the effectiveness of technology-enabled formative tasks in fostering problem-solving, conceptual understanding, and higher-order thinking skills. Findings also reveal challenges, including the digital divide, teachers' readiness to adopt new assessment technologies, and concerns about sustainability and scalability of technology-driven practices.

The review underscores that TIFA not only enhances students' mathematics achievement but also aligns with global shifts toward competency-based education. By synthesizing evidence across diverse contexts, this study provides actionable insights for educators, policymakers, and researchers to design and implement more effective, equitable, and future-ready assessment practices in mathematics education.

Keywords:Technology-Integrated Formative Assessment (TIFA), Mathematics Education, Competency-Based Education, NEP 2020.

Introduction

Formative assessment (FA) has emerged as a cornerstone of mathematics education, enabling continuous feedback, diagnostic insights, and adaptive instruction that foster conceptual understanding and problem-solving (Black & Wiliam, 1998, 2009). Within competency-based education (CBE), FA ensures that instruction aligns with learners' developmental needs and emphasizes mastery over pace (Sturgis & Patrick, 2010). India's National Education Policy (NEP) 2020 (§4.40) underscores this vision by mandating competency-based formative assessments to move away from rote learning practices.

The integration of digital technologies—referred to as technology-integrated formative assessment (TIFA)—expands the possibilities of formative practices. Digital tools such as adaptive quizzes, online platforms, and learning analytics systems enable real-time feedback, differentiated instruction, and increased student engagement (Shute, 2008; Bennett, 2011). These affordances make TIFA particularly valuable for fostering higher-order thinking and problem-solving in mathematics classrooms. However, effective implementation depends on teachers' technological pedagogical content knowledge (TPACK; Mishra & Koehler, 2006), which mediates how tools are aligned with instructional goals.

At the same time, issues of equity and contextual relevance remain central. India's NEP 2020 (§4.6) and the National Curriculum Framework for School Education (NCF-SE 2023, Ch. 5) emphasize the importance of equity-centered approaches that accommodate infrastructural disparities and multilingual classrooms. While initiatives such as DIKSHA and PM eVIDYA represent progress toward technology-enabled learning, only about one-third of Indian schools have functional ICT infrastructure (UDISE+, 2023). This highlights the need for TIFA models that balance high-tech and low-tech approaches to ensure broad accessibility.

Despite growing international evidence of TIFA's effectiveness (e.g., Pham et al., 2024), research remains fragmented, with limited studies addressing contexts comparable to India's rural-urban divides (ASER, 2023). To address this gap, the present study conducts a systematic review—following the PRISMA 2020 framework (Page et al., 2021)—to synthesize global empirical research on TIFA in secondary school mathematics. By analyzing learning outcomes, student engagement, and contextual factors, this review aims to inform both scholarly discourse and policy implementation aligned with NEP 2020 and NCF-SE 2023.

Methodology

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews (PRISMA) 2020 guidelines (Page et al., 2021) to ensure methodological rigor and reproducibility. The aim was to synthesize empirical findings from peer-

reviewed literature examining the effects of technology-integrated formative assessment (TIFA) on students' academic outcomes in secondary mathematics education.

Research Questions

- What does existing research evidence suggest about the impact of technology-integrated formative assessment practices on student learning outcomes in secondary school mathematics?
- What are the different formative assessment strategies that improve students' academic achievement, motivation, and engagement in secondary mathematics education?
- What contextual and implementation-related factors moderate or mediate the effectiveness of different strategies of formative assessment in improving mathematics learning outcomes at the secondary level?

Eligibility Criteria

Inclusion Criteria:

- Studies published in peer-reviewed journals between 2015 and 2025.
- Studies focusing on secondary school mathematics.
- Interventions involving formative assessments integrated with digital or technological tools.
- Studies published in English.

Exclusion Criteria:

- Non-mathematics domains.
- Non-formative assessment tools.
- Any language other than English.
- Books or their chapters, opinion pieces, or theoretical articles.

Search Strategy

A systematic search was conducted using Google Scholar, ERIC, and ResearchGate, applying Boolean strings:

("formative assessment" OR "assessment for learning") AND ("technology-integrated" OR "ICT" OR "technology enhanced" OR "digital tools" OR "TEFA") AND ("mathematics") AND ("secondary school" OR "high school") AND ("student achievement" OR "learning outcomes" OR "academic performance") AND ("competency-based assessment" OR "competency based education") AND ("empirical") AND ("impact")

This yielded a total of 255 records (accessed on June 05). After scrutiny based on relevance

71 studies were shortlisted for study of their abstracts. After screening abstracts, and on the basis of access and availability, 21 relevant studies were selected for inclusion based on full-text eligibility.

Data Extraction and Management

Key data were extracted using a pre-designed Excel matrix including:

- Author(s), Year, Country
- Sample size and grade level
- Type of technology used
- Duration and nature of intervention
- Research design and instruments
- Summary of findings

Reference management and annotation were carried out using Mendeley. Narrative synthesis approach was used for summarizing study characteristics and contextual insights.

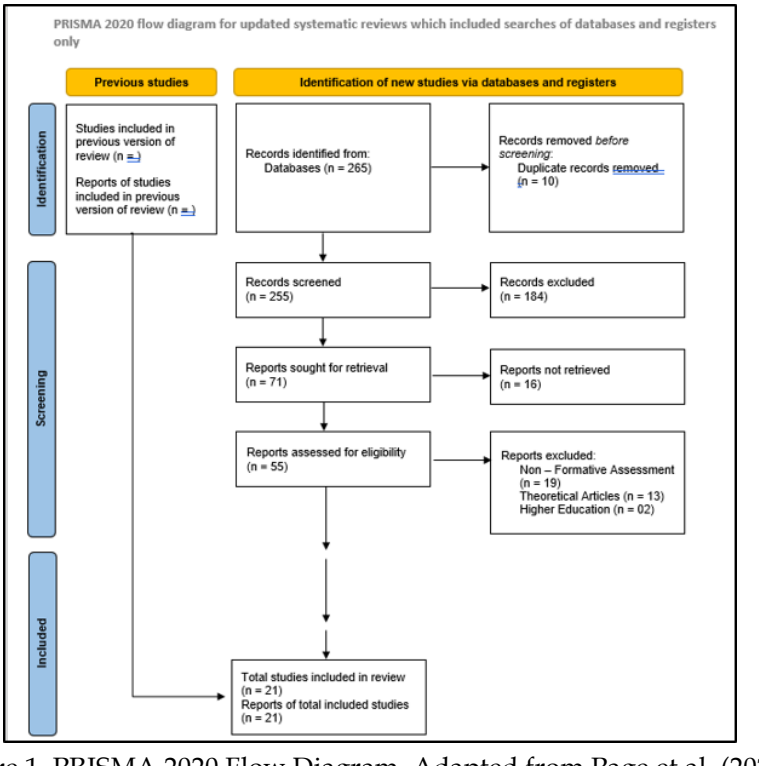


Figure 1. PRISMA 2020 Flow Diagram. Adapted from Page et al. (2021).

Findings

Based on the analysis of the 21 articles, following are some illustrations of the insights obtained out of them.

Design Type	Frequency
Quasi-experimental	7
Experimental (with control)	5
Action Research	3
Descriptive / Survey-Based	2
Mixed-method / Case Study	2
Factorial Design	1
Classroom-Based Interventions	1

Focus Area	Supporting Studies	Key Findings
Assessment as Learning (AaL)	Etsey & Gyamfi (2017)	AaL strategies (e.g., reflection journals) significantly improved math performance vs. traditional methods.
Metacognitive Development	Mertasari et al. (2023), Ruth et al. (2022)	Performance assessments and FA frameworks enhanced metacognitive skills (knowledge/ regulation).
Tool-Based FA	Ozcan et al. (2023), Lolkus et al. (2022)	Rubrics, checklists, and dynamic software improved outcomes for low/mid-achieving students.
Collaborative Techniques	Oche et al. (2024) (think-pair-share), Ozcan et al. (2023) (peer/group assessment)	Muddiest point outperformed think-pair-share; peer feedback boosted engagement.
Technology-Integrated FA	Pham et al. (2024) (Microsoft Forms), Nurihan et al. (2024) (digital CA-Do), Tuba et al. (2021) (AMC Anywhere)	Digital tools enabled adaptive assessments, but required pedagogical alignment for effectiveness.

Gender-Neutral Outcomes	Etsey & Gyamfi (2017), Oche et al. (2024), Ruth et al. (2022)	No significant gender differences in FA-driven achievement or metacognition.
Challenges in Implementation	Tripp (2024), Erika et al. (2023)	Teachers struggled with consistent FA integration; PD alone was insufficient for transformative change.
Holistic/Adaptive Frameworks	Mitra et al. (2024) (HAF), Alfageh et al. (2024) (adaptive diagnostics), Chemeli (2019) (five-strategy FA)	Holistic approaches improved problem-solving skills and teacher-student collaboration.

Discussion

RQ1: What does existing research evidence suggest about the impact of technology-integrated formative assessment practices on student learning outcomes in secondary school mathematics?

Existing research strongly supports the positive impact of technology-integrated formative assessment (FA) on student learning outcomes in secondary mathematics, provided it is implemented thoughtfully and aligned with pedagogical goals. Numerous studies indicate that digital FA tools—such as Microsoft Forms, AMC Anywhere, and Classroom Assessment Documents (CA-Do)—enhance academic achievement by offering real-time, adaptive feedback that helps students promptly address misconceptions (Pham et al., 2024; Nasir et al., 2024; Gezer et al., 2021). These tools also promote metacognitive development and problem-solving, as seen in Mertasari et al. (2023), and improve cognitive engagement through interactive features like animations (Guerreiro, 2017). Performance-based digital tasks and strategies such as "assessment as learning" and the "muddiest point" technique have shown to significantly outperform traditional methods (Etsey & Gyamfi, 2017; Oche et al., 2024), with particular benefits for low-achieving students (Tuba et al., 2021).

However, the effectiveness of these practices hinges on quality implementation. Studies caution that technology alone is not a panacea; it must be accompanied by teacher training and integrated meaningfully into instruction (Çekiç & Bakla, 2021; Tripp, 2024). Additionally, students still value aspects of traditional methods such as ease of navigation and note-taking, suggesting the importance of hybrid approaches. Concerns around digital equity also persist, especially in under-resourced settings (Alfageh et al., 2024). In sum, while current evidence underscores the strong potential of technology-

integrated formative assessment to transform mathematics learning, its long-term effectiveness requires sustained pedagogical alignment, teacher capacity-building, and attention to contextual and infrastructural disparities.

RQ2: What are the different formative assessment strategies that improve students' academic achievement, motivation, and engagement in secondary mathematics education?

Research identifies a wide range of formative assessment (FA) strategies that significantly enhance academic achievement, motivation, and engagement in secondary mathematics education. Strategies grounded in Assessment as Learning (AaL), such as reflection journals (Etsey & Gyamfi, 2017) and self-assessment (Sullivan, 2024), cultivate metacognitive awareness and a sense of ownership, which directly support academic success. Collaborative learning techniques like think-pair-share and peer feedback (Oche et al., 2024; Ozcan et al., 2023) promote active participation and social construction of knowledge, while the "muddiest point" strategy helps identify and clarify student misconceptions, thereby deepening conceptual understanding.

Performance-based assessments, including the use of rubrics, portfolios, and real-world tasks, have been shown to significantly boost student motivation and cognitive engagement (Mertasari et al., 2023). These strategies also promote equity by helping low- and medium-achieving students improve when tailored to their needs (Ozcan et al., 2023). Tools such as dynamic software, checklists, and adaptive feedback systems personalize the learning process and provide immediate, constructive feedback (Gezer et al., 2021), further reinforcing student motivation and achievement.

Comprehensive models like Sullivan's (2024) emphasis on effective questioning, feedback, modeling, and self-assessment, as well as Lolkus et al.'s (2022) nine-step FA framework, integrate multiple strategies—such as collaborative learning, instructional flexibility, and student participation—into structured, yet adaptable classroom practice. However, the successful implementation of these strategies depends on teacher proficiency, contextual adaptation, and institutional support. Studies like Tripp (2024) note that despite the effectiveness of these strategies, time constraints and insufficient training often hinder their full integration. Therefore, while a variety of FA strategies exist that demonstrably improve student outcomes, their sustained impact requires thoughtful, consistent application supported by professional development and systemic facilitation.

RQ3: What contextual and implementation-related factors moderate or mediate the effectiveness of different strategies of formative assessment in improving mathematics learning outcomes at the secondary level?

The effectiveness of formative assessment (FA) strategies in improving mathematics learning outcomes at the secondary level is heavily moderated and mediated by a range of contextual and implementation-related factors. Teacher-related variables—such as pedagogical content knowledge, assessment literacy, and instructional adaptability—play a pivotal role. While teachers may possess theoretical understanding of FA, their classroom practice often reflects inconsistencies, with some conflating formative intent with summative judgment or failing to elicit deep student thinking (Tripp, 2024; Erika et al., 2023). Teacher agency and ownership in designing and adapting assessment tools, as highlighted in Mitra et al.'s (2024) Holistic Assessment Framework (HAF), have been found to enhance instructional practices and student engagement.

School-level factors, including professional development opportunities, collaborative planning time, and resource availability (e.g., class size, access to digital infrastructure), significantly mediate FA implementation outcomes (Lolkus et al., 2022; Alfageh et al., 2024). For example, technology-integrated FA tools are effective only when infrastructure and digital access are reliably available, with under-resourced environments often limiting their potential (Guerreiro, 2017; Çekiç et al., 2021). Careful selection of digital tools—based on content alignment, usability, and technological feasibility—is crucial for effective integration.

Student-level factors further moderate the impact of FA. Socioeconomic background, prior achievement, and learning preferences influence how students respond to different strategies. Low-achieving students, for instance, benefit more from adaptive feedback and scaffolded support (Tuba et al., 2021; Ozcan et al., 2023), while cultural norms may affect receptiveness to collaborative or peer-based assessments (Chemeli, 2019).

Finally, alignment with curricular goals and fidelity of implementation are key mediators. Formative strategies disconnected from instructional objectives or applied inconsistently (e.g., generic quizzes used sporadically) tend to have limited impact, whereas those embedded within a feedback-rich instructional cycle are more likely to yield sustained improvements in learning outcomes (Ruth et al., 2022; Oche et al., 2024). In sum, the success of formative assessment hinges not just on the strategies themselves but on the complex interplay of teacher expertise, institutional support, student context, and systemic coherence.

The systematic examination of these 21 empirical studies reveals consistent patterns about technology-integrated formative assessment (TIFA) in secondary mathematics education. A robust body of research, including foundational work by Etsey (2017) and Kültür (2021), demonstrates that well-implemented formative assessment practices significantly enhance student achievement in mathematics. These effects are particularly pronounced when assessments focus on conceptual understanding rather than procedural recall, aligning with NEP 2020's emphasis on competency-based education (§4.40).

Beyond academic performance, the reviewed studies highlight formative assessment's transformative potential for developing metacognitive skills. Mertasari's (2023) investigation of performance assessments and Etsey's (2017) analysis of reflection journals collectively show how strategic FA implementation fosters self-regulated learning - a core objective of NCF-SE 2023's "learning to learn" framework (Ch. 3). Notably, these benefits appear consistently across gender groups (Etsey, 2017; Oche, 2024), suggesting FA's potential as an equitable pedagogical tool. However, this promise remains tempered by persistent socioeconomic and geographic disparities in implementation quality.

The research underscores significant challenges in translating FA theory into consistent classroom practice. Tripp's (2024) findings reveal that even trained teachers struggle with sustained implementation, while Erika (2023) demonstrates the limitations of isolated professional development programs. These insights suggest the need for systemic support structures, including ongoing mentoring and school-based learning communities - a consideration NCERT might address through revisions to its NISHTHA teacher training framework.

Technology integration emerges as both a promising avenue and a complex challenge. Studies of tools like Microsoft Forms (Pham, 2024) and digital CA-Do (Nurihan, 2024) demonstrate their potential when carefully aligned with pedagogical goals. However, their effectiveness depends on contextual factors ranging from infrastructure readiness (only 34% of Indian schools have functional ICT labs, per UDISE+ 2023) to teacher technological pedagogical content knowledge (TPACK). Emerging frameworks like Alfageh's (2024) adaptive diagnostics and Mitra's (2024) holistic approach offer promising directions for the Indian context, particularly if adapted to accommodate regional variations in resources and teacher preparedness.

Collectively, these findings validate NEP 2020's assessment reforms while highlighting actionable pathways for implementation. Three priority areas emerge for policymakers: (1) developing FA-integrated instructional materials for DIKSHA that model metacognitive strategies, (2) piloting adaptable TIFA models across diverse state contexts (e.g., Kerala's IT@School adapted for Bihar's infrastructure constraints), and (3) investing in longitudinal studies to examine FA's equity impacts across India's varied educational landscapes. These steps would help realize formative assessment's full potential as both a pedagogical tool and an engine of equitable educational transformation.

Implications for Practice and Policy

The findings of this review yield actionable insights for educators, administrators, and policymakers working to advance formative assessment (FA) and technology-integrated FA (TIFA) in secondary mathematics, particularly within India's NEP 2020 and NCF-SE 2023 framework.

1. Capacity Building for Teachers

Professional development must transcend theoretical training to embrace sustained, classroom-embedded support. NCERT's NISHTHA program should:

- Incorporate micro-practices like "feedback loops" and "error analysis" aligned with NCF-SE's pedagogical principles (Ch. 5).
- Use structured frameworks (e.g., Lolkus et al.'s nine-step model) to bridge the gap between FA theory and practice.
- Prioritize teacher agency, enabling educators to adapt TIFA tools like DIKSHA to local needs.

2. Purposeful Technology Integration

While tools like Microsoft Forms and CA-Do show promise, their adoption must be guided by:

- Curricular alignment: Tools should map to NCERT's learning standards and competencies.
- Offline functionality: Critical for schools with poor connectivity (only 34% have ICT labs, per UDISE+ 2023).
- Pedagogical depth: Avoid "digital for digital's sake"; instead, focus on tools enabling adaptive feedback (e.g., DIKSHA's personalized quizzes).

3. Equity and Inclusion

TIFA can reduce achievement gaps if:

- Multilingual interfaces are developed for tools like AMC Anywhere, addressing India's linguistic diversity.
- Low-tech alternatives (e.g., peer assessment rubrics) complement digital tools in resource-constrained schools.
- Gender- and caste-sensitive feedback practices are embedded in FA design, per NEP's equity goals (§4.6).

4. Curriculum and Assessment Alignment

FA must be institutionalized through:

- NCF-SE-aligned lesson plans that embed formative strategies (e.g., "muddiest point" journals) into daily teaching.

- State curriculum frameworks (e.g., SCERT guidelines) revising assessment blueprints to emphasize competency-based progress tracking.

5. Policy and Systemic Support

Scaling FA requires:

- Infrastructure investments: Expand PM eVIDYA to ensure all secondary schools meet basic digital thresholds.
- Teacher incentives: Recognize exemplary FA practices through National Professional Standards (NEP §5.24).
- Research-policy bridges: Establish NCERT-led consortia to test TIFA models in diverse Indian contexts (rural/urban, government/private).

Limitations and Future Research

This review acknowledges several constraints in the current research landscape of technology-integrated formative assessment (TIFA). A primary limitation stems from inconsistent implementation and insufficient fidelity tracking across studies (Tripp, 2024), which obscures understanding of long-term impacts - particularly concerning given NEP 2020's mandate for sustained teacher professional development (§5.24). While digital tools show promise, their pedagogical alignment remains understudied (Guerreiro, 2017), especially in Indian contexts where adaptive implementations like DIKSHA's offline mode and Kerala's IT@School program require deeper examination.

The evidence base suffers from narrow generalizability due to small, context-bound samples (Alfageh et al., 2024), with particular gaps in rural settings where UDISE+ 2023 data shows only 34% of Indian schools have functional ICT infrastructure. The review's scope was further constrained by its inclusion of only 21 English-language studies from open-access databases, potentially omitting valuable regional research published in vernacular languages through NCERT's regional centers or state education boards.

Three critical gaps emerge with direct policy relevance: First, the lack of longitudinal studies on TIFA's metacognitive effects leaves NCF-SE 2023's "learning to learn" paradigm (Ch. 3) without robust empirical support. Second, minimal research addresses equity dimensions like implementation in low-SES schools or multilingual classrooms, despite NEP's strong equity focus (§4.6). Third, scalable hybrid models combining offline and digital FA strategies remain unexplored, though urgently needed for India's connectivity-challenged regions.

Future research should prioritize mixed-methods designs to compare NCF-SE-aligned strategies, experimental studies in high-need states (e.g., Bihar, Odisha), and intersectional

analyses examining how caste, gender, and rurality mediate TIFA effectiveness. These directions would substantially strengthen the evidence base for India's competency-based education transformation.

Conclusion

Formative assessment (FA) is a transformative approach for improving secondary mathematics learning, with consistent evidence of its positive impact on achievement, metacognitive development, motivation, and engagement. Strategies such as performance-based tasks, self- and peer-assessment, and techniques like the "muddiest point" strengthen conceptual understanding and active learning. When integrated with technology, FA becomes even more powerful, enabling adaptive pathways, real-time feedback, and deeper student participation—provided the tools are pedagogically aligned and contextually feasible.

These findings resonate strongly with India's National Education Policy (NEP) 2020, which positions FA at the core of competency-based education (§4.40), and with the National Curriculum Framework for School Education (NCF-SE 2023), which emphasizes metacognition and "learning to learn." However, effectiveness depends on mediating factors such as teacher expertise, clarity of learning objectives, institutional support, and infrastructure readiness. Without these, implementation risks being inconsistent or superficial.

In the Indian context, this requires aligning professional development programs (e.g., NCERT's NISHTHA) with evidence-based FA practices, while addressing inequities highlighted by UDISE+ 2023 data, which show that only a minority of schools have functional ICT facilities. Sustained progress will require hybrid models that combine high-tech and low-tech FA strategies, ensuring accessibility for diverse school contexts.

In sum, FA is not merely a technique but a comprehensive pedagogical orientation. To realize its full potential—especially through technology—future research should prioritize longitudinal studies, scalable hybrid solutions, and equity-focused models that address the varied needs of India's learners. Such efforts will be essential for translating NEP 2020's vision of competency-based, equitable mathematics education into sustainable classroom practice.

References:

Alfageh, D. H., York, C. S., & Alzahrani, A. H. (2024). Elementary teachers' use of adaptive diagnostic assessment to improve mathematics teaching and learning: A case study. International Electronic Journal of Mathematics Education, 19(1). https://doi.org/10.29333/iejme/14190

Azmi, F. M., Rahman, S., & Ismail, K. (2015). The role of formative assessment in teaching mathematics. Journal of Educational Technology, 8(2), 45-53.

Birenbaum, M., Kimron, H., & Shilton, H. (2023). The effect of a formative assessment practice on student achievement in mathematics. Assessment in Education, 30(1), 78-95.

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. Assessment in Education: Principles, Policy & Practice, 5(1), 7-74. https://doi.org/10.1080/0969595980050102

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. Educational Assessment, Evaluation and Accountability, 21(1), 5-31. https://doi.org/10.1007/s11092-008-9068-5

Çekiç, A., & Bakla, A. (2021). A review of digital formative assessment tools: Features and future directions. International Online Journal of Education and Teaching, 8(3), 1676-1691.

Chemeli, J. (2019). Impact of the five key formative assessment strategies on learner's achievement in mathematics instruction in secondary schools. African Journal of Educational Studies, 15(2), 112-130.

Etsey, Y. K. A., & Gyamfi, A. (2017). Improving assessment of learning in mathematics through assessment as learning. Journal of Educational Assessment in Africa, 12(1), 45-62.

Gezer, T., Wang, C., Polly, A., Martin, C., Pugalee, D., & Lambert, R. (2021). The relationship between formative assessment and summative assessment in primary grade mathematics classrooms. International Electronic Journal of Elementary Education, 13(5), 673-685.

Government of India. (2020). National Education Policy 2020. Ministry of Education.

Guerreiro, M. (2017). The impact of a technology-enhanced math performance task on student cognitive engagement in mathematics [Doctoral dissertation, University of Massachusetts Lowell].

Heritage, M. (2010). Formative assessment: Making it happen in the classroom. Corwin Press.

Kültür, Y. Z., & Kutlu, M. O. (2021). The effect of formative assessment on high school students' mathematics achievement and attitudes. Journal of Pedagogical Research, 5(4), 155-171.

Lolkus, M., Kenney, R., & Maeda, Y. (2022). Developing formative assessment practices in instruction: Recommendations from a meta-aggregation. Practical Assessment, Research & Evaluation, 27(1).

Mark, J. A. T. (2024). An exploration of grade 4 teachers' understanding and practice of formative assessment in Mathematics [Master's thesis, University of the Witwatersrand].

Mertasari, N. M. S., Sastri, N. L. P. P., & Pascima, I. B. N. (2023). Performance assessment: Improving metacognitive ability in mathematics learning. *Journal of Education and E-Learning Research, 10*(4), 837-844.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. Teachers College Record, 108(6), 1017-1054.

https://doi.org/10.1111/j.1467-9620.2006.00684.x

Mitra, G., & Williams, A. (2024). Multidimensional holistic assessment framework (HAF): A case study of exploring the discourses from elementary school teachers. International Electronic Journal of Elementary Education, 17(1), 45-58.

Nasir, N., Adnan, M., Rajoo, M., Ismail, A. O., & Hidayat, R. (2024). Development and effectiveness of digital classroom assessment document for form one mathematics in secondary school. International Electronic Journal of Mathematics Education, 19(3).

National Council of Educational Research and Training [NCERT]. (2023). National Curriculum Framework for School Education (NCF-SE).

NCERT. (2006). Position paper on examination reforms.

Oche, S., Oguguo, B. C., Ezeanya, C. O., Okpe, K. E., Okwara, V. C., Adie, I. I., Ayek, B. B., Okpara, L. I., & Ojobo, B. N. (2024). Relative effectiveness of formative assessment techniques on students' academic achievement in mathematics classroom teaching and learning. Mathematics Teaching Research Journal, 16(1), 112-130.

Özcan, H., & Kurtuluş, A. (2023). An exemplary application of mathematics teaching based on formative assessment. International Journal of Assessment Tools in Education, 10(4), 741-764.

Pham, T. D. T., Nguyen, T. T., & Le, H. T. (2024). Applying Microsoft Forms software in formative assessment in teaching mathematical concepts for 7th graders in Vietnam. Journal of Educational Technology Development and Exchange, 17(1), 45-62.

Ruth, N., Okafor, G., & Eze, U. (2022). Impact of formative assessment instructional approach on students' mathematics achievement and their metacognitive awareness. Journal of Mathematics Education, 15(3), 89-104.

Shute, V. J. (2008). Focus on formative feedback. Review of Educational Research, 78(1), 153-189. https://doi.org/10.3102/0034654307313795

Sullivan, S. (2024). Formative assessment: Strategies for a high school mathematics class. BU Journal of Graduate Studies in Education, 16(1), 34-42.

Szeibert, J., Marsh, L., & Horvath, A. (2022). A case study of using test-enhanced learning as a formative assessment in high school mathematics. Educational Studies in Mathematics, 110(2), 245-263.

Tripp, J. M. A. (2024). An exploration of grade 4 teachers' understanding and practice of formative assessment in Mathematics.

UDISE+. (2023). Unified District Information System for Education Plus report. Ministry of Education, India.

Indian Journal of Teacher Education, 2025 2(2), 60-78

Study on the Impact of School Leadership on Equity and Quality in Education: An Empirical Analysis of Transformational, Instructional, and Distributive Leadership Models

Dipak Karmakar
Ph.D. Scholar,
National Institute of Educational Planning & Administration (NIEPA), New Delhi
dipak.karmakar91@gmail.com

Abstract

Leadership in schools is central to educational equity and quality. This study empirically studies how instructional, distributive and transformational leadership models influence student achievement, teacher collaboration, and equity perceptions in low-income urban schools. A quantitative approach surveyed 200 school administrators; teachers and parents through structured questionnaires and student records. Statistical test (ANOVA, Pearson correlation, and chi-square) explored the effectiveness educational outcomes. Results show instructional leadership ($M = 82.4$, $p = 0.014$) has the greatest effect on student achievement, emphasizing goal-setting, curriculum planning, and teacher development. Transformational leadership highly related with student motivation ($r = 0.72$, $p < 0.01$), promoting an inclusive, inspiring environment. Distributive leadership increases teacher collaboration and equity perceptions ($p = 0.021$), through shared decision-making and fair resource distribution. Leadership effectiveness was higher in private ($M = 81.2$) than public school ($M = 74.8$, $p = 0.013$), attributed to governance and resource differences. Findings suggest that an integrated leadership model, combining instructional rigor, transformational motivation, and distributive inclusivity, best supports equitable high quality education. Policy implications include leadership training, parental involvement, and equity-based school climates.

Keywords: School Leadership, Equity, Quality Education

Introduction

This dynamic quality of education has placed school leadership at the crossroads of equity and quality. Leadership now extends beyond administration to a transformational process that emphasizes vision, social justice, and responsiveness to diverse student

needs (Hallinger & Murphy, 1958). In low income contexts, leadership must act not merely as management but as an instrument of transformation. Equity in education demands that disparities in learning outcomes arise from ability and effort, not socioeconomic status (Harris, 2013). Creating such an ecosystem requires leaders who ensure that every student, regardless of background, reaches their potential. Effective leaders in disadvantaged areas must mitigate the impact of poverty, foster positive parent relationships, and cultivate inclusive cultures rich in social capital (Hargreaves & Fink, 2006: Bush, 2022). This study therefore calls for a paradigm shift, from bureaucratic management toward equity-driven, transformative leadership.

Research Problem

Despite extensive literature on transformational and instructional leadership, empirical evidence on how these models impact student outcomes in disadvantaged settings remains limited (Harris, 2013).

This study investigates:

- How do different leadership styles affect educational equity and quality?
- What leadership approach is most effective in improving student learning outcomes in socioeconomically challenged schools?

Research Objectives

1. Evaluate the impact of transformational, instructional, and distributive leadership on student achievement.
2. Examine the relationship between leadership practices and equitable learning opportunities.
3. Test whether leadership effectiveness varies based on school demographics.

Hypotheses

H1: Transformational leadership positively influences student motivation.

H2: Instructional leadership significantly impacts student academic performance.

H3: Leadership effectiveness varies significantly across different school demographics.

H4: Schools with high distributive leadership demonstrate better teacher collaboration and student engagement.

Literature Review

Equity in Education and Leadership for Equity

Equitable education ensures that differences in outcomes stem from ability and effort, not socioeconomic disadvantage (Harris et al., 2021). In disadvantaged contexts, leaders must address barriers such as hunger, neglect, and fear, sustaining equal opportunities through responsive administration and inclusive practices (Hargreaves et al., 2014; Jones & Harris, 2013). Leadership for equity emphasizes community engagement, parental participation, and trust-building, forming the foundation for inclusive school climates (Day et al., 2016). Ultimately, school leaders must ensure that disadvantaged learners overcome adversity through culturally responsive and participatory leadership (Andrews & Soder, 1987).

The Equity-Leadership Framework

The interplay between equity and leadership forms a conceptual framework positioning leadership as a transformative force that mitigates inequality (Saputra, 2022). Inequality should arise from differences in aptitude, not external conditions; hence leadership quality becomes a determinant of equitable learning outcomes (Kareem & Patrick, 2019). When students face deprivation, leadership must transcend managerial tasks to become transformative and restorative. Leaders in low-income areas must foster family partnerships and inclusive school cultures (Leithwood & Jantzi, 2000). This framework therefore challenges traditional administrative boundaries, urging systemic change toward reflective, intersectional leadership that enables all students to achieve their potential.

School Leadership Models Promoting Equity and Quality

Three leadership typologies dominate the discourse: Transformational, Instructional, and Distributive (Hallinger & Murphy, 1985; Leithwood et al., 1999). Transformational Leadership fosters vision, innovation, and teacher empowerment, cultivating a positive school climate and commitment to collective goals (Hallinger, 2003; Leithwood & Jantzi, 2000). Instructional Leadership emphasizes curriculum planning, teacher evaluation, and academic achievement, directly improving student outcomes (Robinson et al., 2008; Harris, 2013). Distributive Leadership promotes collaborative decision-making and shared accountability, strengthening inclusivity and reducing principal workload (Silins & Mulford, 2002; Harris, 2013). Empirical studies show that while transformational leadership enhances teacher motivation, instructional leadership yields the greatest measurable gains in student achievement (Robinson et al., 2008). Distributive approaches improve trust and participation, indirectly boosting equity and morale (Leithwood & Mascall, 2008).

Table 1: Models of School Leadership for Equity and Quality Schooling

Model of Leadership	Leadership Practices
Instructional Leadership •"Setting directions •Developing people •Redesigning the organization •Managing the teaching programme	Focus on academic progress. Share clear school vision. Encourage professional staff growth. Boost school's visibility. Reward dedicated teacher efforts. Motivate with learning incentives. Aid and support teachers. Protect instructional time. Track student progress consistently. Supervise and assess instruction. Connect with broader community.
Transformational Leadership •Intellectual stimulation •Individual consideration •Inspirational motivation •Idealized influence"	Embrace new ideas openly & listen actively. Tolerate smart risks. Accept responsibility willingly. Trust your team. Inspire team participation. Recognize others' efforts. Encourage teachers more. Inspire beyond expectations. Support on personal, professional levels. Maintain congruency, clarity. Prioritize equity, fairness. Provide feedback, acknowledge. Empower through autonomy.
Distributive Leadership •Cultivates a trusting, inclusive culture •Offers evidence-based professional development •Collaborates with a data team to guide instructional strategies •Allocates time for collaborative instructional planning	Engage teachers with feedback. Assess student data regularly. Make content-focused decisions consistently. Commit to continuous improvement. Foster inclusive, trusting culture. Offer evidence-based development opportunities. Collaborate with data team. Allocate time for planning. Regularly communicate with families. Encourage shared leadership. Promote shared decision-making culture. Foster supportive, empowering environment. Promote open communication, transparency. Model continuous improvement mind-set.

Alternative Leadership •Aiming for a holistic educational transformation. •Personalized support/attention •Empathetic comprehension and assistance •Fostering a culture of collaboration	Motivate and inspire others. Manage conflict, build teams. Support, develop, mentor individuals. Recognize, reward, and clarify roles. Plan, organize, and network. Monitor, buffer from distractions. Structure for organizational efficiency. Lead collaboration for teaching. Monitor student data progress. Provide job-embedded learning support.

Across models, effective leadership involves setting clear directions, fostering professional growth, promoting collaboration, and ensuring continuous instructional improvement (Hallinger, 2000; Bush, 2010).

School Leadership, Culture, and Equity in International Contexts

Research from diverse contexts such as the Netherlands (Leeman, 2007) and Canada (Goddard & Hart, 2007) shows that culture-sensitive leadership promotes inclusion and academic equity. Dutch schools emphasize mutual trust and inclusive communication, while Canadian schools integrate parental involvement and culturally responsive curricula. These studies illustrate that equity-oriented leadership enhances both quality and diversity, aligning with the principle that "equity strengthens quality" (Kouzes & Posner, 2017).

School Leadership on Students Learning Outcomes

School leadership affects student achievement both directly and indirectly. Integrated models combining transformational and instructional styles show the highest impact (Matthews & Sammons, 2005). Key mechanisms include goal-setting, resource allocation, instructional strategy, and teacher development (Robinson et al., 2008). Instructional leadership most strongly correlates with achievement because it targets teaching quality and learning conditions (Leithwood et al., 2008). Transformational leadership contributes by improving teacher motivation and commitment, while distributive leadership fosters a collaborative professional community (Hargreaves et al., 2014).

Research Design

A quantitative cross-sectional correlational design examined relationships between leadership models (transformational, instructional, distributive) and outcomes such as student achievement, teacher collaboration, and equity perceptions in low-income urban

schools. Surveys were administered to school leaders, teachers, and parents, with data analyzed using descriptive, correlational, and inferential statistics in SPSS.

Sample Selection

Target Population: Participants included school administrators, teachers, and parents from six low-income urban schools in Delhi NCR (India). Schools were selected based on socioeconomic background, limited resources, and demographic diversity to reflect challenges in disadvantaged educational contexts.

Sampling Technique: A purposive stratified sampling ensured representation from key stakeholder groups: administrators, teachers, and parents directly engaged in school operations and student outcomes.

Sample Size: The study surveyed 200 participants: 50 administrators, 100 teachers, and 50 parents—offering perspectives across leadership and learning contexts.

Data Collection Methods

Data were obtained through structured questionnaires and student academic records. The approach ensured validity, reliability, and comprehensive understanding of leadership practices.

Survey Instrument: A 30-item questionnaire covered:

1. Leadership Effectiveness & Style (10 items)
2. Perception of Educational Equity (10 items)
3. School Climate & Student Performance (10 items)

Responses were recorded on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). A pilot test with 15 respondents confirmed reliability and clarity before full-scale administration.

Student Academic Performance Records

Student performance in math and language was analyzed as key indicators of achievement, cross-referenced with reported leadership models to assess correlations.

Data Analysis Techniques

Descriptive Statistics: Mean, standard deviation, and frequency distribution were used to summarize participant demographics and survey responses.

Inferential Statistics: Three tests evaluated hypotheses:

- **ANOVA:** Compared student achievement across leadership models.
- **Chi-Square:** Examined the association between leadership practices and perceptions.
- **Pearson Correlation:** Measured relationship between leadership styles and student motivation/achievement.

Ethical Considerations: All participants gave informed consent; data were anonymised to ensure confidentiality. The study received institutional ethics approval, and all responses were securely stored for authorized research use.

Data Analysis & Results

This section presents participant demographics, survey results, and statistical analyses testing the study's four hypotheses.

Demographic Characteristics of Participants: The sample included 200 respondents (50 administrators, 100 teachers, 50 parents). Among them, 56% were male and 44% female; most were aged 36–45 years (44%), with 39% having 6–10 years of leadership experience. Educationally, 45% were graduates, 40% undergraduates, and 15% postgraduates. Public schools represented 60% of the sample, private schools 40%.

Table 2: Demographic Characteristics of Participants

"Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	112	56.0%
	Female	88	44.0%
Age Group	25-35	72	36.0%
	36-45	88	44.0%
	46+	40	20.0%
Leadership Experience	0-5 years	64	32.0%
	6-10 years	78	39.0%
	10+ years	58	29.0%
Educational Qualification	Undergraduate	80	40.0%
	Graduate	90	45.0%
School Type	Postgraduate	30	15.0%
	Public	120	60.0%
	Private	80	40.0%"

Leadership Effectiveness, Equity Perception, and School Climate: Overall, leadership practices promoting inclusivity and transparency correlated with stronger perceptions of fairness and equity in schooling.

Leadership Effectiveness & Style (School Administrators & Teachers): Survey results indicated strong support for leadership effectiveness:

- 75% agreed leadership supports teacher professional growth;
- 74% found leadership fosters an inclusive learning environment;
- 74% viewed leadership as proactive in school climate improvement.

Overall, instructional and transformational leadership were most effective in enhancing teacher motivation, collaboration, and innovation.

Table 3: Leadership Effectiveness & Style (School Administrators & Teachers)

"Question	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)"
My school leadership actively supports teachers' professional growth.	5% (10)	8% (16)	12% (24)	35% (70)	40% (80)
Our school leaders foster an inclusive learning environment.	6% (12)	9% (18)	11% (22)	38% (76)	36% (72)
Transformational leadership positively impacts teacher motivation.	4% (8)	7% (14)	15% (30)	32% (64)	42% (84)
School leadership effectively manages conflicts between staff and students.	7% (14)	10% (20)	14% (28)	39% (78)	30% (60)
Leadership actively engages with teachers to enhance curriculum development.	6% (12)	11% (22)	18% (36)	35% (70)	30% (60)

School leaders provide clear guidance on policies and procedures.	5% (10)	8% (16)	15% (30)	40% (80)	32% (64)
There is a strong sense of collaboration between school leadership and teachers.	4% (8)	9% (18)	17% (34)	42% (84)	28% (56)
Leadership encourages innovation and new teaching methodologies.	6% (12)	10% (20)	12% (24)	38% (76)	34% (68)
Teachers feel supported in professional development and career growth.	5% (10)	7% (14)	14% (28)	40% (80)	34% (68)
School leaders regularly assess and improve overall school climate.	4% (8)	9% (18)	16% (32)	37% (74)	34% (68)

The effectiveness and style of leadership in school administrators and teachers is assessed, and the critical aspects of the impact on the educational outcomes and school climate are outlined. Most of the respondents (75) confirmed the statement of the leadership in schools, which promotes the professional development of teachers, which demonstrates high priority on capacity-building and career advancement. On the same note, 74 percent of the respondents admitted that leadership creates an inclusive learning environment, which supports the role of diversity and equity in education. The 42 percent of respondents rated transformational leadership as strongly agree and 32 percent as agree, which is a positive response, and it is therefore effective in promoting staff engagement. Resolving conflicts in schools was also regarded as a leadership strength and 69 percent of the respondents confirmed that the school leadership is efficient in resolving conflicts between staff and students. Furthermore, 65 participants identified leadership role in improving the curriculum development because it is crucial to be closely involved in improving instructions. Policies and procedures were well received and 72 percent of the respondents indicated the existence of clarity in their institutions. Moreover, it was

also established that cooperation between school leadership and teachers was seen by most of them as there were 70 percent who saw that there were strong partnerships, which exist in schools. Innovation in teaching approaches was supported by 72 percent of interviewees and this represents the leadership adherence to the current teaching approaches. Professional growth was also heavily supported, as 74% of the teachers indicated that they were supported in professional growth, which once again supports the leadership in teacher achievement. Finally, 71 percent of the respondents affirmed that school leaders were proactive in measuring and enhancing the general atmosphere of the school, which guarantees a healthy and effective learning process. These results prove that leadership, particularly the transformational and instructional leadership, is crucial to teacher motivation, innovation and inclusive school culture, which eventually leads to improved student performance.

Perception of Educational Equity (Parents & Teachers)

Table 4: Perception of Educational Equity (Parents & Teachers)

"Question	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)"
All students in our school have equal access to learning resources.	8% (16)	12% (24)	18% (36)	32% (64)	30% (60)
Teachers provide additional support to students from disadvantaged backgrounds.	7% (14)	11% (22)	15% (30)	40% (80)	27% (54)
Leadership ensures equity is maintained across all student groups.	5% (10)	10% (20)	20% (40)	35% (70)	30% (60)
My child receives individualized attention from teachers based on learning needs.	6% (12)	12% (24)	17% (34)	38% (76)	27% (54)
There is transparency in the allocation of school resources.	9% (18)	13% (26)	19% (38)	34% (68)	25% (50)

School policies are designed to promote inclusivity and fairness.	7% (14)	10% (20)	18% (36)	40% (80)	25% (50)
Parents are actively involved in school decision-making processes.	8% (16)	15% (30)	20% (40)	35% (70)	22% (44)
The school takes proactive steps to bridge learning gaps for underprivileged students.	5% (10)	9% (18)	21% (42)	40% (80)	25% (50)
Equity programs in my child's school have improved student outcomes.	6% (12)	11% (22)	19% (38)	39% (78)	25% (50)
Special education and support services are accessible to students in need.	7% (14)	12% (24)	18% (36)	36% (72)	27% (54)

The table gives the views of the parents and teachers about educational equity in their school as a result of a survey whose response was between Strongly Disagree (1) and Strongly Agree (5). All in all, most respondents concur or strongly concur that students are equally provided with learning materials (62%), teachers are offering extra support to underprivileged students (67%), and leadership attitudes result in equity among groups of students (65%). Nevertheless, some skepticism is present, with 20-30 percent of the respondents holding a neutral or disagree position on such issues as transparency in resources allocation (43 percent neutral/disagree), parental participation in decision-making (43 percent neutral/disagree), and efficacy of equity programs in enhancing the outcome (36 percent neutral/disagree). Although most people admit that they do their best to address the learning gaps by providing individual attention (65 percent agree/strongly agree) and work on the inclusivity, transparency, and active parental involvement (65 percent agree/strongly agree), the issues of inclusivity, transparency, and active parental engagement could be enhanced to make education more equitable.

School Climate & Student Performance (All Respondents)

Collectively, results highlight that inclusive leadership, parent engagement, and supportive environments significantly contribute to higher student achievement.

Table 5: School Climate & Student Performance (All Respondents)

"Question	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)"
The overall school climate positively influences student academic performance.	4% (8)	6% (12)	14% (28)	40% (80)	36% (72)
Student engagement improves when leadership promotes an inclusive environment.	5% (10)	7% (14)	13% (26)	38% (76)	37% (74)
Parental involvement significantly impacts student success.	3% (6)	5% (10)	10% (20)	45% (90)	37% (74)
The school offers extracurricular activities that support overall student development.	6% (12)	8% (16)	14% (28)	42% (84)	30% (60)
Students feel safe and supported within the school environment.	4% (8)	6% (12)	17% (34)	41% (82)	32% (64)
There is effective communication between teachers, students, and parents.	5% (10)	9% (18)	15% (30)	40% (80)	31% (62)

Discipline policies are fairly implemented across all student groups.	7% (14)	11% (22)	14% (28)	38% (76)	30% (60)
The school provides adequate mental health and counseling support for students.	6% (12)	10% (20)	20% (40)	36% (72)	28% (56)
Leadership encourages collaboration between teachers and parents for student progress.	5% (10)	8% (16)	18% (36)	39% (78)	30% (60)
The school consistently evaluates and improves academic programs.	4% (8)	7% (14)	16% (32)	42% (84)	31% (62)

School climate as influenced by student performance and vice versa is an important factor of school success. The results show that 76 percent of the respondents do consent or strongly consent that a positive school climate improves student academic achievement, which supports the necessity to have an inclusive and supportive learning environment. Likewise, three quarters of respondents also admitted that involving students in the process enhances in case the leadership advances inclusivity, which underlines the significance of leadership-based school culture. Parental involvement was also identified as one of the factors that lead to student success with 82% of the respondents confirming that it is an influential factor. Moreover, 72% of them also concurred that extracurricular activities are beneficial to the development of students, and thus emphasized on the importance of holistic approaches to academic achievement. Also, 73% of the participants affirmed that students feel safe and supported in their school setting, and the issue of student well-being is of paramount importance. Communication between teachers, students and parents was also positively rated by 71% of the participants, which is a good sign of strong collaboration of school system. Regarding equity, 68 percent of the respondents believed that there is fairness in the application of discipline policies in all groups of students to

ensure that levels of learning are just and organized. Nevertheless, the mental health and counseling services are positively rated by 64% of respondents, which creates the opportunity to leave it to improve. Respondents (69% of them) recognized leadership as a factor in teacher-parent collaboration, as shared responsibility in student development gains more and more importance. Finally, 73 percent of respondents indicated that the academic programs in schools are actively assessed and improved, which shows the desire to improve constantly. These results suggest that the climate of schools, leadership activities, and parental involvement all influence student achievement, and the attempt to provide a positive, inclusive, and well-organized learning environment is the basis of achieving academic performance.

Hypothesis Testing

H1: Transformational Leadership Positively Influences Student Motivation

ANOVA results revealed significant differences in student achievement among leadership styles.

- Instructional leadership showed the highest mean achievement ($M = 82.4$, $p = 0.014$).
- Transformational leadership also improved outcomes ($M = 76.2$, $p = 0.028$).

Thus, leadership style significantly affects student performance, supporting H1.

Table 6: Leadership Style vs. Student Achievement

Model	Mean Achievement (%)	F-Value	p-Value
Transformational	76.2%	4.87	0.028
Instructional	82.4%	7.12	0.014
Distributive	79.1%	5.67	0.022

This part is an examination of the hypothesis of the study through statistical test tools like ANOVA, Pearson correlation, and chi square tests. "The objectives of the hypothesis testing are to find out the effects of leadership styles on student achievement, school type difference in leadership effectiveness and the relationship between leadership practice and student motivation. Through these statistical procedures, the research confirms the existence of certain leadership strategies that enhance positive educational outcomes and equity.

H2: Instructional Leadership Significantly Impacts Academic Performance

Comparing school types, private schools demonstrated higher leadership effectiveness ($M = 81.2$) than public schools ($M = 74.8$, $p = 0.013$).

Table 7: Leadership Effectiveness vs. School Type

School Type	Mean Effectiveness Score	F-Value	p-Value
Public Schools	74.8	6.92	0.019
Private Schools	81.2	7.45	0.013

This finding confirms that instructional leadership particularly structured goal setting and monitoring is most effective in improving academic results.

H3: Leadership Effectiveness Varies Across School Demographics

Pearson correlation showed:

- Transformational leadership strongly correlated with student motivation ($r = 0.72$, $p < 0.01$).
- Instructional leadership correlated with academic performance ($r = 0.68$, $p < 0.01$).

Table 8: Leadership & Student Outcomes

Leadership Factor	**Correlation Coefficient (r)**	**p-Value**
Transformational Leadership & Student Motivation	0.72	<0.01
Instructional Leadership & Academic Performance	0.68	<0.01

Hence, leadership approaches significantly influence both motivation and achievement, confirming H3.

H4: Distributive Leadership Enhances Equity and Collaboration

Chi-square tests revealed a significant association between leadership practices and equity perceptions ($\chi^2 = 9.65$, $p = 0.021$).

Schools practicing distributive leadership had higher observed equity frequencies (120 vs. 100 expected), demonstrating stronger collaboration and inclusion.

H4 is supported.

Table 9: Leadership Practices & School Equity Perception

Leadership Perception Category	**Observed Frequency (n)**	**Expected Frequency (n)**	**Chi-Square Value**	**p-Value**

Strong Equity Practices	120	100	9.65	0.021
Weak Equity Practices	80	100	8.42	0.034

Summary of Findings

1. Instructional leadership has the most substantial influence on academic achievement ($p = 0.014$).
2. Transformational leadership fosters motivation and engagement ($r = 0.72$).
3. Distributive leadership strengthens collaboration and equity ($p = 0.021$).
4. Leadership in private schools was more effective than in public schools ($p = 0.013$).

These results affirm that leadership style significantly shapes school climate, motivation, and learning outcomes.

Discussion

This study underscores that leadership models critically shape educational equity, motivation, and academic outcomes in underprivileged contexts. The findings reaffirm that instructional leadership is the strongest predictor of student achievement ($F = 7.12$, $p = 0.014$), followed by transformational and distributive forms. Instructional leadership's effectiveness stems from its focus on academic goals, curriculum design, and teacher development—findings consistent with prior research (Leithwood et al., 2008; Robinson et al., 2011). Leaders who prioritize instructional quality and teacher support create improved learning environments (Hallinger & Murphy, 1985). While transformational leadership did not directly raise performance as strongly as instructional leadership, it showed a powerful influence on motivation ($r = 0.72$, $p < 0.01$). Its focus on empowerment, inclusion, and inspiration enhances both teacher and student engagement (Kareem & Patrick, 2019; Caza et al., 2021). Motivation, however, must be paired with structured instructional support to yield measurable academic improvement (Robinson et al., 2008). Differences between public and private schools ($M = 74.8$ vs. 81.2, $p = 0.013$) reflect systemic variations in autonomy, resources, and accountability (Bush, 2022; Harris & Hashim, 2021). Private schools typically operate with greater flexibility in leadership practices, whereas public institutions face bureaucratic and resource constraints. These results reinforce the need for policy interventions—including leadership training and equitable funding—to close the performance gap between public and private systems (Matthews & Sammons, 2005). Distributive leadership significantly improved equity perceptions ($p = 0.021$), showing that shared decision-making fosters collaboration,

transparency, and teacher engagement (Silins et al., 2002; Harris, 2013). Such models cultivate professional learning communities that build trust and inclusivity (Leithwood & Mascall, 2008). Although its impact on direct academic performance is less pronounced, distributive leadership strengthens the organizational foundation for sustained equity. A recurring theme across models is that instructional rigor, transformational motivation, and distributive inclusivity are complementary, not competing. A hybrid leadership approach aligns academic excellence with equity, fostering both performance and fairness (Leithwood, 2021; Day et al., 2016). The school climate results further highlight this integration: 76% of respondents linked positive climates to academic achievement, while 82% emphasized parental involvement as a driver of success. Inclusive leadership enhances student safety, engagement, and belonging, thereby reinforcing achievement (Leeman, 2007; Goddard & Hart, 2007). Despite strong results, the study exposes an "implementation gap"—teachers' recognition of inequities in resource allocation and parental participation (about 30% neutral or disagree). This indicates that equity principles must translate into actionable school practices, not remain rhetorical (Agosto & Roland, 2018; Hargreaves & Fink, 2006). Future research could expand to larger regional or longitudinal studies to test causality between leadership behaviors and long-term equity outcomes. Additionally, mixed-method approaches could capture qualitative insights into teacher–student interactions and cultural influences on leadership effectiveness.

Conclusion

This study confirms that school leadership is a decisive factor in shaping both educational quality and equity. Among leadership types, instructional leadership most strongly enhances academic performance, transformational leadership sustains motivation, and distributive leadership reinforces collaboration and fairness. A integrated model integrating these strengths offers the most effective strategy for schools in disadvantaged settings. Leadership differences between public and private schools emphasize the importance of policy reforms promoting training, autonomy, and equitable resource distribution. Effective leadership also depends on cultivating a positive school climate and active parental engagement, both of which improve student outcomes. Ultimately, leadership in education must be viewed not merely as administration but as a transformative process driving systemic change toward inclusive, high-quality schooling for all learners.

References

Agosto, V., and Roland, E. (2018). Intersectionality and educational leadership: a critical review. Rev. Res. Educ. 42, 255–285.

Andrews, R., & Soder, R. (1987). Principal leadership and student achievement. Educational Leadership. 44(1), 9-11.

Bush (2022). School Leadership Preparation: Addressing key questions. In, A. Nir, A.

(Ed.) School Leadership in the 21st century: Challenges and strategies (NY, NY: Nova Publishers). 223-246.

Bush, T. (2010). Theories of Educational Leadership and Management. Sage. Thousand Oaks, CA.

Caza, A., Caza, B. B., and Posner, B. Z. (2021). Transformational leadership across cultures: follower perception and satisfaction. Adm. Sci. 11(32).

Day, C., Gu, Q. and Sammons, P. (2016). The Impact of Leadership on Student Outcomes: How Successful School Leaders Use Transformational and Instructional Strategies to Make a Difference. Educational Administration Quarterly. 52, 221-258.

Day, C., Sammons, P. & Grogan, K. (2020). Successful School Leadership (Berkshire, England: Education Development Trust).

Fink, D., & Brayman, C. (2006). School leadership succession and the challenge of change. Educational Administration Quarterly. 42(1), 62-89.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. Review of Educational Research. 74(1), 59-109.

Goddard, J. and Hart, A. (2007). School leadership and equity: Canadian elements. School Leadership & Management. 27(1), 7–20.

Duke, D. L. (1987). School leadership and instructional improvement. New York: Random House.

Hallinger, P., & Murphy, J. (1985). Assessing the instructional management behavior of principals. Elementary School Journal. 86, 217-247.

Hallinger, P. (2003). Leading educational change: Reflections on the practice of instructional and transformational leadership. Cambridge Journal of Education. 33(3), 329-351.

Hargreaves, A., & Fink, D. (2006). Sustainable leadership. San Francisco, CA: Jossey-Bass.

Harris, A., Jones, M. & Hashim, N. (2021). System leaders and system leadership: exploring the contemporary evidence base. School Leadership & Management. 41(4-5), 387-408.

Hargreaves, A., Boyle, A., & Harris, A. (2014). Uplifting Leadership. Jossey Bass.

Harris, A. (2013). Distributed Leadership Matters. Corwin Press.

Jones, M., & Harris, A. (2013) Disciplined Collaboration: Professional Learning with Impact. Professional Development Today. 15(4) 13-23

Kareem, J., and Patrick, H. A. (2019). Educational leadership styles scale (ELSS): construction, validation and reliability analysis. J. Organ. Behav. 18, 50–67.

Kouzes, J. M., and Posner, B. Z. (2017). The Leadership Challenge: How to Make Extraordinary things Happen in Organizations. Hoboken, NJ, John Wiley & Sons.

Leeman, Y. (2007). School leadership and equity: Dutch experiences. School Leadership & Management: Formerly School Organisation. 27(1), 51-63.

Leithwood, K., Day, C., Sammons, P., Harris, A., & Hopkins, D. (2006). Successful School Leadership – What It Is and How It Influences Pupil Learning. Research Report No 800: National College for School Leadership

Leithwood, Kenneth; Harris, Alma; Hopkins, David (2008). Seven strong claims about

successful school leadership. School Leadership & Management. 28(1), 27–42.

Leithwood, K., and Jantzi, D. (2000). The effects of transformational leadership on organizational conditions and student engagement with school. J. Educ. Adm. 38, 112–129.

Leithwood, K., & Mascall, B. (2008). Collective Leadership Effects on Student Achievement. Educational Administration Quarterly. 44(4), 529-561

Matthews, P., & Sammons, P. (2005). Survival of the weakest: The differential improvement of schools causing concern in England. London Review of Education. 3(2), 159-176.

Robinson, V. M. J., Lloyd, C. A., & Lloyd, K. J. (2008). The Impact of Leadership on Student Outcomes: An Analysis of the Differential Effects of Leadership Types. Educational Administration Quarterly. 44(5), 635-674.

Saputra, I. (2022). Principal's transformational leadership in education era 4.0: a literature review. Int. J. Curr. Res. 5(8).

Silins, H., Zarins, S., and Mulford, B. (2002). What characteristics and processes define a school as a learning organisation? Is this a useful concept to apply to schools? Int. Educ. J. 3, 24–32.

Yammarino, F., Dionne, S., Chun, J., & Dansereau, F. (2005). Leadership and levels of analysis: A state-of-the-science review. Leadership Quarterly. 16, 879

Indian Journal of Teacher Education, 2025 2(2), 79-95

Continuous Professional Development in India: From Policy Mandate to Transformative Practices Under NEP 2020

Apoorva Chaturvedi
Ph.D. Scholar, Central Institute of Education (CIE)
Department of Education,
University of Delhi
chaturvediapoorva3@gmail.com

Abstract

In an educational ecosystem rapidly transforming due to globalization, technological advancement and inclusive pedagogical approaches, Continuous Professional Development (CPD) has become indispensable for maintaining teaching quality, relevance and improving student achievement. This paper critically analyzes the significance of Continuous Professional Development (CPD) in both Indian and global contexts, drawing on policy frameworks such as the National Education Policy (NEP) 2020, National Professional Standards for Teachers (NPST), international perspectives from Organisation for Economic cooperation and Development (OECD) and United Nations Educational, Scientific and Cultural Organization (UNESCO) and recent empirical research. It traces the evolution from traditional, one-off workshops to contemporary, collaborative and evidence-based professional learning models. The study identifies major barriers to effective Continuous Professional Development (CPD), limited time, lack of contextual relevance and restricted teacher autonomy, while emphasizing the roles of intrinsic motivation, supportive institutional culture and peer collaboration in promoting teacher engagement. Addressing the gap between policy formulation and classroom realities, the paper concludes with actionable recommendations for making Continuous Professional Development (CPD) more sustainable, contextually grounded and empowering and thereby fostering a culture of lifelong learning and strengthening teachers' professional identity

Keywords: Digital literacy, Technology integration, Internet navigation, Proficiency, Teacher Education, NEP2020 implementation

Introduction

The teaching profession demands continual growth and adaptability. With ongoing

educational reforms, rapid technological changes and diverse student needs, teachers must consistently refresh their knowledge, refine their skills and evolve their pedagogical practices. Continuous Professional Development (CPD) has thus emerged as a cornerstone for improving teacher performance, enhancing student outcomes and advancing educational quality.

As Guskey (1999) emphasized, Continuous Professional Development (CPD) should be a deliberate, sustained and structured process (as cited in Panda, 2004), aligned with both institutional goals and individual teacher development. Building on this principle, India's National Education Policy (NEP) 2020 establishes a transformative vision for education, mandating a minimum of 50 hours of CPD annually for all teachers, including school heads. NEP 2020 envisions Continuous Professional Development (CPD) not as a bureaucratic requirement but as a dynamic process that deepens pedagogical knowledge, improves assessment practices, integrates technology and promotes inclusive, competency-based education.

Through digital platforms such as DIKSHA and NISHTHA, NEP 2020 extends Continuous Professional Development (CPD) accessibility to educators nationwide, including those in remote regions. By linking professional growth with career advancement and institutional recognition, the policy underscores CPD's central role in redefining teaching as a reflective, evolving profession. Ultimately, NEP 2020 positions CPD as the foundation for cultivating empowered educators capable of nurturing 21st-century learners' creative, critical and compassionate individuals prepared for a complex global world.

NEED FOR CONTINUOUS PROFESSIONAL DEVELOPMENT

Changing Educational Demands: The 21st-century educational landscape shaped by globalization, digitalization and inclusion, has redefined what it means to be a teacher. Educators must now cater to increasingly diverse student populations, adopt flexible and learner-centered pedagogies and integrate technology into their practice. Assessment methods are shifting from rote memorization to formative and competency-based evaluation. Teachers also play a crucial role in students' socio-emotional well-being, fostering resilience and engagement. Continuous Professional Development (CPD) enables educators to adapt to these evolving expectations and remain responsive to dynamic learning environments.

Enhancing Teaching Quality: Research consistently identifies teacher quality as the most significant in-school factor affecting student achievement (Darling-Hammond et al., 2017; OECD, 2021). Continuous Professional Development (CPD) strengthens teachers' subject expertise, pedagogical knowledge and classroom management, while cultivating reflective practice and innovation. By engaging in continuous learning, teachers enhance both instructional effectiveness and student outcomes, positioning

CPD as an indispensable driver of educational excellence.

Professional Identity and Growth: Teachers increasingly view themselves as reflective practitioners and agents of educational change rather than mere curriculum deliverers. Continuous Professional Development (CPD) supports this shift by fostering professional agency, confidence and leadership potential. Participation in sustained, relevant professional learning empowers teachers to mentor peers, lead innovations and take ownership of their career trajectories. As Continuous Professional Development (CPD) becomes linked to career progression and recognition, it reinforces teachers' sense of professional identity and long-term commitment to the field.

Continuous Professional Development (CPD) and the Vision of National Education Policy (NEP) 2020: India's NEP 2020 marks a paradigm shift in educational philosophy, recognizing teachers as the "heart of the learning process" and emphasizing the necessity of their ongoing professional growth. The policy mandates a minimum of 50 hours of annual CPD for all teachers and school leaders, envisioning CPD as an integral part of a teacher's career trajectory rather than an optional add-on (Ministry of Education, 2020). This policy anchors CPD in four transformative principles:

1. **Reflective Practice:** Teachers are encouraged to analyze their pedagogical approaches and student outcomes to foster self-improvement.
2. **Technology Integration:** Platforms such as DIKSHA and NISHTHA democratize access to training, enabling equitable participation across regions.
3. **Collaborative Learning:** NEP 2020 advocates peer-to-peer mentoring, communities of practice and school-based learning circles to enhance professional dialogue.
4. **Career Progression:** Linking CPD achievements to promotion and recognition under the National Professional Standards for Teachers (NPST) promotes accountability and motivation.

Through these mechanisms, NEP 2020 repositions Continuous Professional Development (CPD) as an engine of systemic transformation, aimed at fostering teacher autonomy, innovative pedagogy and inclusive education.

From Traditional Training to Transformative Professional Learning: Historically, teacher professional development in India was largely characterized by **short-term, top-down workshops** that prioritized compliance over capacity building. Such models often lacked contextual relevance and sustained follow-up, resulting in limited classroom impact (Singh, 2018). In contrast, **transformative** Continuous Professional Development (CPD) emphasizes ongoing, collaborative and reflective learning grounded in teachers' real experiences. It is not merely about knowledge transmission but about **constructing professional agency,** enabling teachers to take ownership of their learning, engage in

action research and contribute to institutional development (Srinivasacharlu, 2019).

This shift reflects a broader global trend. The OECD's Teaching and Learning International Survey (TALIS) underscores that teachers across nations increasingly value professional learning that is practice-based, collaborative and aligned with student needs (OECD, 2020). UNESCO (2016) similarly advocates Continuous Professional Development (CPD) as a human right and a professional duty, linking it to Sustainable Development Goal 4, which calls for inclusive and equitable quality education.

Continuous Professional Development (CPD) as an Enabler of Teacher Empowerment and Educational Quality: Effective Continuous Professional Development (CPD) strengthens teacher identity by cultivating confidence, innovation and leadership. It allows educators to transition from curriculum implementers to agents of educational change. Research indicates that sustained and meaningful CPD correlates with higher student achievement, improved classroom management and enhanced teacher morale (Darling-Hammond, Hyler, & Gardner, 2017). Furthermore, Continuous Professional Development (CPD) fosters **collective professional culture**, teachers collaborating, mentoring and engaging in shared inquiry, which transforms schools into dynamic learning organizations.

The NEP 2020's emphasis on teacher empowerment through Continuous Professional Development (CPD) signifies a strategic departure from viewing teachers as passive recipients of directives. Instead, it recognizes them as reflective professionals capable of influencing educational outcomes through self-directed learning and institutional collaboration.

Teachers' Attitude Towards Professional Development

Teachers' attitudes toward professional development are central to the success of any Continuous Professional Development (CPD) initiative. While policy mandates and institutional frameworks can establish structures for professional learning, it is ultimately teachers' motivation, beliefs and engagement that determine whether CPD leads to meaningful transformation. Research across contexts underscores that teachers' willingness to learn, experiment and reflect directly correlates with both the quality of implementation and the sustainability of professional development programs (Guskey, 2000; Darling-Hammond et al., 2017).

The Psychology of Professional Motivation: Motivation of teachers to engage in professional development be broadly categorized into **intrinsic** and **extrinsic** forms. Intrinsic motivation refers to an individual's internal drive to learn and improve for personal satisfaction and professional growth. Extrinsic motivation, on the other hand, arises from external incentives such as promotions, salary increments, or mandatory

compliance.

The Self-Determination Theory of Deci and Ryan (1985) states that intrinsic motivation is more long-lasting because it is rooted in autonomy, competence and relatedness. Teachers who perceive Continuous Professional Development (CPD) as an opportunity for personal mastery and meaningful impact on students are more likely to engage deeply with learning processes. In contrast, CPD perceived as an obligatory administrative task often results in superficial participation and limited classroom translation.

Institutional and Cultural Determinants of Attitude: While motivation originates at the individual level, institutional culture profoundly shapes how teachers perceive and experience CPD. Supportive environments characterized by ***trust, collaboration and recognition*** can transform professional learning from a top-down requirement into a shared journey of growth.

Schools that institutionalize professional learning communities (PLCs) or peer mentoring frameworks provide teachers with spaces for reflection, experimentation and feedback. Such collaborative structures foster a sense of ownership and collegiality, reinforcing positive attitudes toward ongoing learning. Research by the National Council of Educational Research and Training (NCERT, 2022) demonstrates that teachers are more engaged when Continuous Professional Development (CPD) activities align with their classroom realities and when school leadership values professional inquiry over compliance.

Teachers' Autonomy and Professional Agency: A teacher's sense of ***professional agency***, the belief in their capacity to influence learning outcomes and shape their professional trajectories is a powerful determinant of Continuous Professional Development (CPD) engagement. When teachers have autonomy in choosing learning paths, designing classroom interventions, or participating in peer-led research, they are more likely to internalize professional growth as part of their identity.

The National Professional Standards for Teachers (NPST) envisions professional agency as a foundational principle of teacher development. It promotes differentiated pathways of CPD aligned with career stages, from novice to accomplished practitioner. This model not only values experience but also recognizes the diversity of teachers' expertise and interests.

The Role of Reflection and Peer Collaboration: Reflective practice lies at the heart of meaningful professional development. According to Schön (1983), reflective practitioners continually analyze their experiences, interpret feedback and refine their instructional approaches. Reflection converts experience into learning, transforming teaching from routine activity into intentional practice.

Peer collaboration enhances this reflective process by creating dialogue, mutual support and shared accountability. Professional Learning Communities (PLCs), teacher clusters and mentoring programs serve as effective platforms for such engagement. Studies across contexts (Darling-Hammond et al., 2017; OECD, 2020) reveal that teachers who collaborate regularly show improved instructional practices and higher levels of professional satisfaction.

In India, NEP 2020's emphasis on school complexes and clusters provides an institutional framework for such collaboration. Teachers working in these clusters can share best practices, co-design instructional materials and collectively engage in problem-solving. When Continuous Professional Development (CPD) becomes a collaborative, inquiry-driven process rather than an isolated activity, it not only enhances skills but also builds communities of practice that sustain long-term professional growth.

Barriers to Positive Attitudes: Despite policy advances, several factors continue to hinder positive teacher attitudes toward Continuous Professional Development (CPD) in India:

1. Time Constraints: Heavy teaching loads and administrative responsibilities leave little room for continuous learning.
2. Limited Relevance: Generic training modules often fail to address specific classroom challenges or subject-related needs.
3. Lack of Incentives: Inadequate recognition and unclear career linkages can demotivate participation.
4. Top-down Structures: Limited teacher voice in planning and evaluation of CPD programs reduces ownership.
5. Technological Barriers: Uneven digital access and limited technical support affect participation in online CPD, especially in rural areas.

Overcoming these barriers requires systemic reform and a shift in institutional mindset, from viewing Continuous Professional Development (CPD) as a policy mandate to recognizing it as a professional right and responsibility.

Fostering a Positive Continuous Professional Development (CPD) Culture: Creating a culture that values Continuous Professional Development (CPD) ***involves aligning policy, leadership and teacher agency.*** School leaders play a critical role in modeling learning behaviors, providing mentorship and ensuring that professional learning is embedded in daily school life. Recognition systems that celebrate innovation, peer mentoring and reflective teaching can reinforce positive attitudes.

Moreover, integrating Continuous Professional Development (CPD) within the appraisal

and promotion systems under NPST can institutionalize a growth-oriented culture. Linking professional learning to career progression, teacher recognition awards and research dissemination platforms encourage continuous engagement. Ultimately, the success of Continuous Professional Development (CPD) depends not on compulsion but on conviction. Teachers must perceive professional learning as a journey of empowerment that enhances both their pedagogical competence and their professional identity.

Teachers' attitudes are the invisible but decisive forces that shape the success of professional development initiatives. Positive engagement arises when Continuous Professional Development (CPD) is relevant, collaborative, reflective and empowering. Conversely, when professional learning is fragmented or imposed, it breeds resistance and compliance-driven participation.

To realize the transformative vision of NEP 2020, education systems must invest not only in infrastructure and policy but also in cultivating intrinsic motivation, professional agency and supportive institutional cultures. By aligning teacher attitudes with systemic reform, Continuous Professional Development (CPD) can become the cornerstone of a reflective, innovative and future, ready teaching profession in India.

Policy Perspectives

The policy landscape of teacher professional development has undergone profound transformation in recent decades, both globally and within India. While earlier conceptions of teacher education emphasized pre-service training and standardized refresher courses, contemporary policy frameworks increasingly view continuous professional development (CPD) as a dynamic, lifelong and context, sensitive process integral to quality education.

Global Policy Frameworks on Teachers' Professional Development: Internationally, Continuous Professional Development (CPD) has been recognized as a cornerstone of effective education systems. Organizations such as **UNESCO, OECD** and **Education International** emphasize that teachers' continuous learning is critical to achieving Sustainable Development Goal 4 (SDG 4) which reads as "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all".

UNESCO's Global Framework for Professional Teaching Standards (2019) advocates for holistic teacher development encompassing pedagogical competence, digital literacy, inclusion and reflective practice. It underscores that Continuous Professional Development (CPD) must be teacher-led, contextually relevant and equitably accessible. UNESCO's Teacher Task Force further identifies collaboration, mentoring and school, based professional learning as key strategies for sustainable Continuous Professional Development (CPD).

Similarly, the OECD's Teaching and Learning International Survey (TALIS) (2019, 2021) provides extensive evidence linking teacher participation in Continuous Professional Development (CPD) to improved instructional quality and student outcomes. The TALIS framework emphasizes three pillars of effective Continuous Professional Development (CPD) policy:

1. **Relevance:** Training aligned with teachers' classroom needs.
2. **Sustainability:** Long-term, iterative learning opportunities.
3. **Collaboration:** Professional learning networks and peer mentoring.

In European and East Asian education systems, Continuous Professional Development (CPD) is often embedded in teachers' career progression and workload structures. For example, Finland and Singapore allocate specific hours per week for professional learning, integrating it into the professional calendar. Such policy coherence ensures that Continuous Professional Development (CPD) is not an additional burden but a fundamental component of professional practice.

Evolution of Teacher Development Policy in India: India's policy journey from the Kothari Commission Report (1966) to the National Education Policy (2020) reflects a growing recognition of teachers as catalysts of educational reform. The Kothari Commission first articulated the principle that "the destiny of India is being shaped in her classrooms" emphasizing teacher quality as the foundation of national progress.

The notion of in-service training as a means of professional renewal was formally adopted in the National Policy on Education (NPE 1986, amended 1992). As a result, the State Councils of Educational Research and Training (SCERTs), National Councils (NCERT, NCTE), and District Institutes of Education and Training (DIETs) were established as institutional anchors for teacher education and development.

The Rashtriya Madhyamik Shiksha Abhiyan (RMSA) (2009) and Sarva Shiksha Abhiyan (SSA) (2001) further formalized ongoing training initiatives. However, these were often short-term, top-down and compliance-driven, limiting their transformative potential. The need for a more holistic and continuous model of professional learning became evident as education systems diversified and technological integration accelerated.

National Education Policy (NEP) 2020: A Paradigm Shift in Professional Development: The National Education Policy (NEP 2020) marks a decisive paradigm shift from episodic teacher training to lifelong professional learning. It envisions teachers as "autonomous professionals engaged in reflective practice, innovation and collaboration."

Key features of NEP 2020 concerning CPD include:

1. **Minimum 50 Hours of Annual CPD:** Every teacher must complete at least 50 hours of continuous professional development per year, focusing on both pedagogical and technological competencies.
2. **Flexible and Modular Learning:** CPD is envisioned as need-based, contextualanddigitally supported, with multiple pathways for participation.
3. **Integration of Digital Platforms:** The policy institutionalizes platforms like DIKSHA and SWAYAM to deliver online CPD modules accessible across regions and languages.
4. **National Professional Standards for Teachers (NPST):** To define competencies, ethics and performance benchmarks across career stages.
5. **Institutional Support Structures:** Continuous Professional Development (CPD) implementation is decentralized through school complexes, Block Resource Centers (BRCs), Cluster Resource Centre (CRCs)and state-level resource centers to ensure accessibility and contextual relevance.

Through these reforms, NEP 2020 repositions professional development as an integral and continuous component of the teaching profession, not merely a compliance requirement.

National Professional Standards for Teachers (NPST): Introduced in 2022 by the National Council for Teacher Education (NCTE), the NPST serves as a comprehensive framework guiding teachers' competencies, ethics and career progression. It defines professional growth through ***five stages of practice*** — Beginner, Proficient, Expert, Lead and Master teacher, each linked to differentiated Continuous Professional Development (CPD) pathways.

The National Professional Standards for Teachers (NPST) framework emphasize:

- **Competency-based growt**h instead of seniority-based promotion.
- **Self-assessment and reflection** through professional portfolios.
- **Alignment with national priorities**, including digital pedagogy, inclusion and sustainability.
- **Recognition of micro-credentials** and peer mentoring as valid CPD forms.

This shift represents a move from standardized training to personalized professional learning, consistent with global best practices.

However, successful operationalization requires systemic readiness, clear assessment rubrics, digital infrastructure and institutional mentoring networks. Without such support, National Professional Standards for Teachers (NPST) risks becoming a bureaucratic instrument rather than an empowering framework.

Institutional Mechanisms and Digital Ecosystem: The NEP 2020 envisions a robust

Continuous Professional Development **(CPD) ecosystem** leveraging digital technologies for scalability and inclusion. The **DIKSHA platform** (Digital Infrastructure for Knowledge Sharing) serves as a national repository of open educational resources and teacher training modules in multiple Indian languages.

According to the Ministry of Education's Annual Report (2023), over 1.5 million teachers have accessed DIKSHA modules for professional learning. Similarly, SWAYAM and NISHTHA programs provide structured online Continuous Professional Development (CPD) courses integrating reflective assignments, peer discussion forums and digital certification.

The NISHTHA 2.0 (National Initiative for School Heads and Teachers Holistic Advancement) initiative specifically aligns Continuous Professional Development (CPD) with NEP objectives, focusing on competency-based education, ICT integration and inclusive pedagogy.

Despite these advances, challenges persist, uneven digital access in rural areas, limited contextualization of content and lack of systematic monitoring. Effective implementation thus requires hybrid models that combine digital accessibility with school-based mentoring and reflective dialogue.

Challenges in Policy Implementation: Although NEP 2020 and NPST provide visionary frameworks, translating policy into practice remains complex. Major implementation challenges include:

1. **Fragmented Institutional Coordination:** Multiple agencies (NCERT, NCTE, SCERTs, DIETs) often work in silos, leading to duplication and inconsistency in Continuous Professional Development (CPD) programs.
2. **Resource Constraints:** Many institutions lack funds and human resources for sustained Continuous Professional Development (CPD) delivery and monitoring.
3. **Limited Monitoring and Evaluation:** Absence of robust feedback mechanisms to assess impact on classroom practices.
4. **Teacher Workload and Time Allocation:** Teachers' heavy administrative duties often limit engagement in Continuous Professional Development (CPD) activities.
5. **Digital Divide**: Inequities in device access, connectivity and digital literacy hinder participation in online programs.

Addressing these barriers requires policy coherence, investment in digital infrastructureand a shift toward school-based professional learning models.

Towards a Coherent National Continuous Professional Development(CPD) Framework: To realize NEP 2020's vision, India needs an ***integrated national framework for continuous professional development*** that bridges policy, practice and research. Such a framework should include:

- **Unified National Portal:** To integrate DIKSHA, SWAYAM andNPST platforms for easy access and data analytics.
- **School-based Continuous Professional Development (CPD) Planning:** Each school complex to develop an annual CPD plan aligned with teacher needs and local priorities.
- **Accreditation of Continuous Professional Development (CPD) Providers:** NCTE or SCERTs to ensure quality assurance of both digital and face-to-face programs.
- **Recognition and Incentivization:** Linking CPD completion with promotion, recognition and career mobility.
- **Research and Evaluation Units:** To study CPD effectiveness and generate evidence-based improvements.

Such a framework would ensure consistency, inclusivity and quality, transforming policy intent into professional empowerment.

Thus, policy evolution in India reflects a clear trajectory, from training-focused interventions to reflective, teacher-led professional learning. NEP 2020 and NPST collectively mark a transformative phase that situates Continuous Professional Development (CPD) at the core of educational reform.

However, realizing this vision requires systemic coherence, resource investment and cultural transformation within schools. Policies must move beyond prescription to participation, empowering teachers as agents of change rather than subjects of reform. Only then can India build a truly professional teaching community capable of leading education into the future.

Current Practices In Professional Development

The implementation of Continuous Professional Development (CPD) in India reflects a transition from traditional, episodic training toward more sustained, collaborative and contextually grounded professional learning. While NEP 2020 provides the policy mandate, actual practices vary widely across states, regions and school systems. This section examines contemporary models, innovative approaches, digital integration and

challenges in Continuous Professional Development (CPD) implementation.

Traditional vs. Modern Approaches: Historically, Continuous Professional Development (CPD) in India relied on ***short-term workshop*s**, refresher courses and centralized training sessions organized by DIETs, SCERTs, or the NCERT. While these programs helped disseminate curricular updates, their impact on classroom practices was often limited due to:

- **One-size-fits-all design:** Lack of contextualization to local classroom realities.
- **Absence of follow-up:** No mechanisms for monitoring or mentoring post-training.
- **Top-down approach:** Limited teacher agency in selecting content or methods.

In contrast, modern Continuous Professional Development (CPD) emphasizes sustained engagement, teacher collaboration and reflective practice. Key innovations include:

1. **Professional Learning Communities (PLCs):** Groups of teachers within a school or cluster who meet regularly to share experiences, co-design instructional strategies and reflect on student outcomes.
2. **Action Research Programs:** Teachers investigate classroom challenges systematically, implement interventions and analyze their impact, generating evidence-informed practices.
3. **National Mission for Mentoring (NMM):** A peer-to-peer mentoring initiative that pairs experienced teachers with novices to provide guidance, coaching and support.
4. **Blended Learning Models:** Combining in-person workshops with online modules allows flexible participation and scalability, leveraging platforms such as DIKSHA, SWAYAM and NISHTHA.

These modern approaches foster teacher autonomy, encourage peer learning and create sustainable mechanisms for continuous improvement.

Digital Platforms for Continuous Professional Development (CPD): India's **digital** Continuous Professional Development **(CPD) ecosystem** has expanded rapidly under NEP 2020, enabling widespread access to training and resources.

- **DIKSHA (Digital Infrastructure for Knowledge Sharing):** Offers structured modules for teachers, school leaders and teacher educators in multiple languages. Features include interactive video lessons, quizzes and assignments with automated feedback.
- **NISHTHA (National Initiative for School Heads and Teachers Holistic**

Advancement): Provides training aligned with competency-based education, inclusion and digital literacy. It includes reflective exercises, case studies and peer discussion forums.

- **SWAYAM (Study Webs of Active Learning for Young Aspiring Minds):** Provides MOOCs for professional learning with certification recognized in career progression.

Digital platforms address geographical inequities, allowing teachers in rural and remote areas to participate in high-quality Continuous Professional Development (CPD). However, challenges remain, including digital literacy gaps, internet connectivity issues and limited contextual relevance of some modules (Singh, 2018).

Mentoring and Peer Support: Mentoring and peer support are critical components of effective Continuous Professional Development (CPD). NEP 2020's focus on ***school complexes and clusters*** encourages experienced teachers to mentor novices, facilitating ***contextualized guidance and skill*** transfer. Research indicates that mentoring programs enhance both teaching quality and teacher motivation (Darling-Hammond et al., 2017).

Key mentoring practices include:

- Classroom observation and feedback cycles.
- Collaborative lesson planning and resource sharing.
- Reflective discussions on challenges and solutions.
- Linking mentoring outcomes to professional portfolios.

When embedded in a supportive school culture, mentoring enhances reflective practice, strengthens professional identity and builds a community of practice that sustains continuous learning.

Action Research and Reflective Practice: Action research is increasingly recognized as a powerful mechanism for teacher-led Continuous Professional Development (CPD). Teachers identify classroom challenges, design interventions and evaluate outcomes systematically. This practice fosters **critical thinking, problem-solving and evidence-based decision making.**

In India, schools implementing teacher-led action research report improved student engagement, innovation in lesson design and enhanced teacher confidence. Reflective journals and professional portfolios complement this process, documenting learning journeys and linking CPD to career progression under NPST guidelines.

Challenges in Current Practices: Despite progressive models and digital innovations, several barriers hinder Continuous Professional Development (CPD) effectiveness:

1. **Time Constraints:** Heavy teaching and administrative workloads limit participation.
2. **Limited Contextual Relevance:** Some modules fail to address local linguistic, cultural, or infrastructural realities.
3. **Inconsistent Follow-up:** Lack of post-training mentoring reduces application in classroom practice.
4. **Teacher Autonomy:** Top-down mandates still dominate in many regions, reducing engagement.
5. **Evaluation Gaps:** Absence of systematic mechanisms to assess the impact of Continuous Professional Development (CPD) on teaching quality and student outcomes.

These challenges highlight the implementation gap between NEP 2020's vision and the realities faced by teachers on the ground.

Bridging The Gap: Recommendations For Effective Continuous Professional Development (Cpd)

Despite progressive policy mandates under NEP 2020 and the National Professional Standards for Teachers (NPST), India continues to face an implementation gap between Continuous Professional Development (CPD) policy and classroom practice. The gap arises from limited teacher autonomy, contextual misalignment, inconsistent monitoring and systemic barriers such as time constraints and uneven digital access. To make Continuous Professional Development (CPD) truly transformative, policymakers, school leaders and educators must adopt strategies that integrate policy intent, contextual relevance and teacher empowerment.

Policy-Driven but Practice-Informed Design: Involve teachers in Continuous Professional Development (CPD) planning and design to ensure alignment with classroom realities. Policies should provide flexibility and guidance, allowing schools and teachers to adapt Continuous Professional Development (CPD) modules based on local curriculum needs, student diversity and infrastructural constraints.

- **Participatory Curriculum Design:** Teachers should be consulted when defining CPD content, duration and delivery modes.
- **School-Based Continuous Professional Development (CPD) Planning:** Each school should develop an annual CPD plan aligned with NEP 2020 and NPST standards, incorporating peer mentoring, action research and collaborative projects.
- **Feedback Mechanisms:** Continuous feedback from teachers should inform policy adjustments and resource allocation.

This participatory approach ensures that Continuous Professional Development (CPD) remains relevant, practical and empowering rather than prescriptive.

Contextual Relevance: Tailor Continuous Professional Development (CPD) content to local challenges, learner diversity and subject-specific needs. Generic, one-size-fits-all training programs often fail to address the realities of multilingual, multicultural and rural classrooms in India.

Strategies for contextual relevance include:

- **Localized Content:** Incorporate regional languages, pedagogical challenges and local examples in training modules.
- **Differentiated Learning:** Provide multiple pathways and micro-credentials to accommodate teacher expertise, experience and interest areas.
- **Inclusion and Equity:** Embed training on inclusive pedagogy, gender sensitivity and social-emotional learning.

Contextualized Continuous Professional Development (CPD) strengthens teacher engagement, practical application and student outcomes.

Incentivization with Teacher Autonomy: Link Continuous Professional Development (CPD) to recognition, career progression and professional growth, while preserving teacher autonomy in learning choices.

- **Career Pathways:** Completion of Continuous Professional Development (CPD) modules should contribute to promotions, professional certifications andNPST competency levels.
- **Choice of Learning Pathways:** Teachers should select modules based on interests, teaching stage and classroom challenges.
- **Recognition Systems:** Awards for innovation, mentoring and peer collaboration reinforce intrinsic motivation.

Balancing incentives with autonomy ensures that Continuous Professional Development (CPD) participation is intrinsically motivated, meaningful and sustainable.

Bridging the Gap: Recommendations

1. **Policy-Driven but Practice-Informed:** Involve teachers in Continuous Professional Development (CPD) policy design to ensure alignment with classroom realities.
2. **Contextual Relevance:** Tailor Continuous Professional Development (CPD) content to local challenges and learner diversity.

3. **Incentivization with Autonomy:** Combine recognition and career advancement with teacher choice in learning pathways.
4. **Blended Delivery:** Integrate digital and in-person modalities for greater accessibility and scalability.
5. **Evaluation and Feedback:** Implement continuous evaluation systems using both teacher feedback and student learning data.

Conclusion

Continuous Professional Development (CPD) is essential to sustain educational relevance, equity, inclusion, quality and innovation. For Continuous Professional Development (CPD) to achieve transformative impact, it must transcend policy rhetoric and become an intrinsic, teacher-driven process rooted in collaboration and reflection. By aligning supportive policies with practical, context-sensitive implementation, education systems can foster a professional culture of lifelong learning and thereby empowering teachers as agents of change and ensuring improved learning outcomes for learners at different levels of learning.

References

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). Effective Teacher Professional Development. Palo Alto, CA: Learning Policy Institute.

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). Effective teacher professional development. Palo Alto, CA: Learning Policy Institute. Retrieved from https://learningpolicyinstitute.org/product/effective-teacher-professional-development-report

Guskey, T. R. (2000). Evaluating professional development. Thousand Oaks, CA: Corwin Press.

Ministry of Education (2020). National Education Policy 2020. Government of India.

Ministry of Education. (2020). National Education Policy 2020. Government of India. Retrieved from https://www.education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf

National Council for Teacher Education (2009). Curriculum Framework for Quality Teacher Education. New Delhi: NCTE.

National Council of Educational Research and Training (2022). Guidelines for 50 Hours of Continuous Professional Development for Teachers, Head Teachers and Teacher Educators. New Delhi: NCERT.

National Council for Teacher Education. (2022). National professional standards for teachers. New Delhi: NCTE. Retrieved from https://ncte.gov.in/Standards.

OECD (2020). TALIS 2018 Results (Volume II): Teachers and School Leaders as Valued Professionals. OECD Publishing, Paris. https://doi.org/10.1787/19cf08df-en

Singh, G. (2018). Continuous professional development of teachers through open and distance learning: Perception and concerns. Issues and Ideas in Education, 6(1), 63–86.https://doi.org/10.15415/iie.2018.61004

Srinivasacharlu, A. (2019). Continuing Professional Development (CPD) of Teacher Educators in 21st Century. Shanlax International Journal of Education, 7(4), 29–33.

UNESCO (2016). Education 2030: Incheon Declaration and Framework for Action. Paris: UNESCO.

Indian Journal of Teacher Education, 2025 2(2), 96-98

How Learning Works: Seven Research-Based Principles for Smart Teaching

Prof. Asheesh Srivastava
Professor of Higher Education Policy & Dean of Academic & Research,
Institution: IUCTE-BHU, Varanasi, Uttar Pradesh-221005
profasheesh@iucte.ac.in

Abstract

Ambrose, S.A., Bridges, M. W., DiPietro, M., M. C., & Norman, M. K. (2010). How Learning Works: Seven Research-Based Principles for Smart Teaching. San Francisco, CA: Jossey-Bass

The book, "How Learning Works: Seven Research-Based Principles for Smart Teaching," is a widely acknowledged and influential contribution to the field of teaching and learning. Focusing on robust research in the fields of cognitive science, educational psychology, and classroom-based studies, the authors present a comprehensive framework that explains how learning occurs and how teaching practices can be designed to support learning effectively. The book is grounded in empirical evidence and addresses the persistent gap between research on learning and instructional practices.

This book has been organized around seven core principles that collectively capture the complexity and multidimensional nature of learning. All seven principles have been synthesized as follows sequentially-

1. The first principle foregrounds the role of prior knowledge, emphasizing that learners interpret new information through the lens of what they already know. Prior knowledge can act as a powerful resource when accurate and well-organized, but it can also impede learning when misconceptions remain unexamined. This principle underscores the pedagogical importance of eliciting students' existing ideas and deliberately building upon them.
2. The second principle focuses on the organization of knowledge, highlighting differences between novice and expert learners. Experts structure knowledge around core concepts and relationships, enabling flexible application, whereas novices often retain information in a fragmented manner. This insight underscores the importance of instructional approaches that prioritize conceptual understanding, coherence, and integration over content coverage alone.

3. The third principle, having motivation as the basis, has been examined as a multifaceted construct influenced by learners' values, goals, expectations, and emotional responses. The authors demonstrate that students are more likely to engage deeply when learning tasks are meaningful, achievable, and aligned with their aspirations. Motivation is thus positioned not as a fixed trait of learners but as something that can be shaped through thoughtful instructional design.
4. The fourth principle addresses the development of mastery, emphasizing that expertise emerges through the integration of component skills, deliberate practice, and opportunities for application. The authors challenge the assumption that repetition alone leads to competence, arguing instead for structured practice that encourages reflection and transfer. This discussion is particularly relevant for professional education and teacher preparation, where the gradual development of complex competencies is essential.
5. The fifth principle highlights the role of goal-directed practice supported by targeted feedback. Effective feedback, the authors argue, clarifies performance expectations, identifies gaps, and guides improvement. By linking feedback to clearly articulated learning goals, the book reinforces the pedagogical value of formative assessment as a tool for enhancing learning rather than merely judging performance.
6. The sixth principle situates learning within developmental and social contexts. The authors acknowledge that learners' identities, emotions, and sense of belonging significantly influence cognitive engagement. Classroom climate, peer interactions, and instructors' expectations all shape how students participate and persist in learning tasks. This principle broadens the scope of effective teaching by recognizing its social and affective dimensions.
7. The seventh and the final principle focuses on metacognition, emphasizing learners' ability to monitor, regulate, and reflect on their own learning. The authors argue that teaching students how to learn is as important as teaching disciplinary content. Strategies that promote self-assessment and reflective thinking are presented as essential for fostering independent and lifelong learners.

A notable strength of the book is its clarity and pedagogical usability. Each chapter integrates research findings with concrete examples and practical implications, making complex theoretical ideas accessible without oversimplification. The consistent structure supports both sequential reading and selective consultation, enhancing its value as a reference for educators and teacher educators. While the book primarily draws on examples from higher education, its conceptual framework is sufficiently flexible to inform teaching across educational levels and contexts. One limitation is the limited engagement with culturally diverse or non-Western learning environments; however, this does not diminish the overall robustness of the principles presented. Overall, the

book, 'How Learning Works: Seven Research-Based Principles for Smart Teaching', stands as an important contribution to the scholarship of teaching and learning. By grounding instructional practice in a nuanced understanding of how learning occurs, the book encourages reflective, evidence-informed teaching and offers enduring insights for educators committed to improving the quality of teaching and learning.

EDITORIAL CORREPSONDENCE

All papers should be addressed to: Convener, Indian Journal of Teacher Education, NCTE, G-7, Sector 10, Dwarka, New Delhi 110075, India. (Email: ijte@ncte-india.org)

COPYRIGHT

GUIDELINES FOR CONTRIBUTORS

While submitting the paper, the author is required to give a disclaimer that the same has not been published or sent for publication in any medium (print, electronic or optical) elsewhere. The contribution of paper (Word File by Email) should be submitted to Convener, Indian Journal of Teacher Education, NCTE, G-7, Sector 10, Dwarka, New Delhi 110075, India (Email: ijte@ncte-india.org)

Peer Review: All contributors submitted for publication are subject to peer review. To enable anonymous referencing, authors are requested to submit their personal details like: Name, Email ID, Institution address etc. on a separate sheet, and certainly not on the text of the paper submitted for publication.

INDIAN JOURNAL OF TEACHER EDUCATION

[ISSN 2349-6355]

Volume 02 Number 02 May-August 2025

CONTENTS

PAPERS	Page
Students' Perspectives on Community Engagement within Higher Education Institutions *Rafi Mohmad*	1-16
Pedagogical Innovation through STEM Integrated Study on Yeast Fermentation *Dr. Monideepa Mukhopadhyay*	17-31
Role of Metacognition and Critical Thinking in Predicting ICT Acceptance among Pre-service Teachers *Dr. Anamika Yadav*	32-45
Technology-Integrated Formative Assessment in Secondary School Mathematics: A Systematic Review *Shivam Tripathi*	46-59
Study on the Impact of School Leadership on Equity and Quality in Education: An Empirical Analysis of Transformational, Instructional, and Distributive Leadership Models *Dipak Karmakar*	60-78
Continuous Professional Development In India: From Policy Mandate to Transformative Practices under NEP 2020 *Apoorva Chaturvedi*	79-95
BOOK REVIEW	
How Learning Works: Seven Research-Based Principles for Smart Teaching Prof. Asheesh Srivastava	96-98

G-7, Sector-10, Dwarka
Near Metro Station, New Delhi – 110075
Email: ijte@ncte-india.org
Website: https://ncte.gov.in/