ISSN 0971 - 8508

JOURNAL OF TECHNICAL AND VOCATIONAL EDUCATION

VOLUME 26

ISSUE 2

JULY 2025

NATIONAL INSTITUTE OF TECHNICAL TEACHERS TRAINING AND RESEARCH
Institution Deemed to be University under Distinct Category
A Centrally Funded Technical Institute, Ministry of Education, Govt. of India
Taramani, Chennai - 600 113.

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EDITORIAL

We welcome our readers again to this issue of the Journal of Technical and Vocational Education. This journal aims to provide a platform for educators, researchers, policymakers, and industry experts to share their insights, experiences, and research findings on various aspects of technical and vocational education. We envision this journal to catalyse meaningful discussions, collaborations, and innovations that can help shape the future of technical and vocational education in India and beyond. In this inaugural electronic issue of our Journal, we feature a curated selection of articles that showcase the diversity and richness of research and practice in technical and vocational education. We are grateful to our authors, reviewers, and editorial team for their tireless efforts in bringing this issue to fruition.

This edition of the Journal of Technical and Vocational Education presents a diverse collection of research papers that explore cutting-edge technologies, pedagogical approaches, and key aspects of educational equity. These articles offer valuable insights for educators, researchers, and practitioners alike. Key themes and highlights are as follows:

Digital Technologies and Educational Equity

This section begins with a systematic review by Cotrida Namata, Alfred Buluma, and Badru Musisi, titled "Examining Digital Technology's Impact on Equitable Access to Education in Public Higher Institutions: A Systematic Review," which thoroughly investigates how digital tools influence accessibility and fairness in higher education. Complementing this, Chethana H.T, Manjesh R, Trisiladevi C Nagavi, and Aditya C.R present "A Review on Technology in Education for Differently Abled Students," highlighting the transformative potential of technology in creating inclusive learning environments. Furthermore, T.Subha and Jakulin Divya Mary contribute "Bridging the Gap Between Theory and Practice in Rural Education Through Digital Twin Technology," exploring innovative solutions for educational development in rural contexts.

Pedagogy, Learning, and Teacher Professional Development

In this theme, Libin P Oommen, Shan M Assis, and Sushanlal Babu address "Navigating the Decline: Analysis of Psychological Determinants of Student Engagement in Indian Higher Education," offering insights into fostering a more engaging learning environment.

Malliga P introduces an innovative approach in "Experiential Learning Through 360-Degree Video: A Powerful Tool For Educators," showcasing the potential of immersive technologies in pedagogy. Ancha Jerusha, Syeda Ayesha Jahan, and P.Jubin Alex focus on practical skill development in "A Task-Based Approach to Develop Presentation Skills: A Focus on Presentation Competence." Lastly, Sharmila. M explores crucial advancements in professional growth with "Professional Development Practices in Teacher Education Infusing AI: A Professional Development Practices in Teacher Education through Wenger's Communities of Practice," emphasising the integration of AI in teacher training. Murugan Santhanam, Muthumeenakshi Kailasam, B. Sandhya and G. Sree Harine investigate the intricacies of underwater robotics and navigation systems.
Artificial Intelligence and Applications

This section highlights the broad applications of Artificial Intelligence. Tanya Aggarwal discusses the practical implementation of AI in "Implementation of Artificial Intelligence in Business Process Automation," showcasing its role in enhancing efficiency. Expanding on AI's impact, Hussana Johar R B presents "Artificial Intelligence for Disease Detection in Potato Crops under Smart Farming," demonstrating how AI can revolutionise agricultural practices for sustainability and crop health. "AI-Driven Insights For Learning Difficulties In Engineering Education: Predictive Approaches And Solutions" by Harshitha G, Hamsaveni M, and Chethana H T highlights how artificial intelligence assists in understanding challenges in learning.

This edition of the Journal of Technical and Vocational Education offers a valuable resource for researchers, educators, and policymakers seeking to understand and address the critical challenges and opportunities in technology, education, and society. We look forward to receiving your contributions, feedback, and suggestions and to working together to create a vibrant community of scholars and practitioners.

Thank you,

Editor-in-Chief
Journal of Technical and Vocational Education

Examining Digital Technology's Impact on Equitable Access to Education in Public Higher Institutions: A Systematic Review

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ABSTRACT

The purpose of the review is to establish the role of Digital Technology in Promoting Equitable access in Education in public higher institutions. The review adopted a structured review approach; we explored the existing peer-validated sources on the role of digital technology in promoting equitable access in education in public higher institutions. Specifically, we reviewed the role of computers, internet and mobile phones availability in promoting equitable access in Education in higher institutions. The review highlights that digital resources play a crucial role in making educational materials more accessible for students with special needs. Assistive technologies such as screen readers, speech-to-text software, and other adaptive tools support learners with visual, auditory, or motor impairments in engaging with course content. However, policies governing ICT integration have raised concerns about the quality of teaching and learning through digital means, particularly regarding equity in comprehension, adaptation, and the alignment of education systems with evolving technological advancements. These concerns became more pronounced during the COVID-19 pandemic, which rapidly accelerated the use of digital tools in education and sparked discussions about the broader implications of digitalization. Findings from the review indicate that the incorporation of digital technology in higher education institutions extends beyond facilitating equal access to skills for students—it also influences various institutional dynamics and impacts multiple stakeholders.

***Key Words**: Digital technology, Education, Equitable access*

I. INTRODUCTION

Achieving meaningful educational reform is crucial for laying the foundation of long-term economic development, and this hinges largely on fair access to higher education, a central driver of sustainable progress (GN et al., 2024). Advancing equity in higher learning demands a multifaceted approach—tackling systemic obstacles and implementing inclusive policies to ensure students from all backgrounds can thrive (GN et al., 2024). At present, the higher education landscape in Africa continues to face significant challenges and may require more time to reach stability and broaden equitable access. Girls from low-income families, in particular, remain disproportionately affected by gender-based barriers.

As technology becomes increasingly embedded in daily life around the globe, its capacity to enhance fair access to education remains a pressing concern—especially where it falls short of resolving deep-rooted inequalities. By the late 20th century, higher education gained recognition as a vital tool for addressing societal disparities and supporting development efforts. In response, the United Nations prioritized inclusive, high-quality education for all (Okello-Obura, 2010), championing initiatives such as the Millennium Development Goals (MDGs) and the Sustainable Development Goals (SDGs) established in 2015.

A key target within the SDG agenda is to ensure that by 2030, everyone—regardless of gender—can access affordable and quality technical, vocational, and tertiary education, including at the university level (UN, 2015, p. 19). This goal aligns with the 1948 Universal Declaration of Human Rights, which states that higher education should be equally accessible based on ability (UN, 1948, Article 26). Similarly, the 1976 International Covenant on Economic, Social and Cultural Rights echoes this position, advocating for fair entry to higher education through merit-based admissions and a gradual move toward free access (UN, 1976, Article 13, 2c).

Higher education is widely viewed as a cornerstone of progress, as it empowers individuals while contributing to overall societal well-being (Odaga, 2019). Yet challenges remain across Africa, where gender imbalances and structural limitations continue to limit fair participation in tertiary education. Although higher education has expanded in many developing nations, female enrollment continues to lag behind that of their male counterparts. This systematic review investigates the role of digital tools—such as computers, mobile phones, and internet access—in improving educational equity at the higher level, guided by a set of key research questions.

Review Questions

Below are the guiding research questions for the comprehensive review:

RQ1. What is the role of computers availability in promoting equitable access in Education in public higher institutions?
RQ2. What is the role of internet availability in promoting equitable access in Education in public higher institutions?
RQ3. What is the role of mobile phones availability in promoting equitable access in Education in public higher institutions?

II. METHODOLOGY

This portion of the study describes the methodological design followed during the systematic review, outlining the deliberate steps taken to identify, analyze, and consolidate pertinent scholarly material. The research adopted a systematic review strategy, emphasizing a methodical investigation into existing literature on a well-defined subject. This approach involves organizing, analyzing, and synthesizing published findings in order to generate comprehensive and evidence-based insights (Sauer & Seuring, 2023). Data was drawn from prior academic work, assessed and interpreted carefully, and then synthesized through an evaluative process that included critical description, analysis, and summary (Sauer & Seuring, 2023).

The methodology followed the structure of Gough's nine-stage model (Gough, 2007), further elaborated by Bearman and collaborators. This framework requires clearly formulated inclusion and exclusion rules, alongside systematic procedures for searching and filtering results. Major education-focused databases—including ERIC, Scopus, and Web of Science—were used to source literature using targeted search phrases and citation tracking techniques that explored both reference chains forward and backward. Google Scholar served as an additional search tool to expand the literature base.

The review concentrated on academic works published from 2010 through 2024. It drew from peer-reviewed sources such as meta-analyses, policy briefs, review articles, and position papers found in key databases (Scopus, ERIC, Web of Science, and others). Supplementary materials relevant to themes like digital learning tools, educational inclusion, and access equity were also considered.

Keywords

The keywords applied in this review included terms such as ‘Digital technology’, ‘Computers’, ‘Internet’, ‘Smart phones’, and ‘Education Equity and Access’, all narrowed to focus on the context of higher education. Accordingly, a set of precise search criteria was employed across four primary academic databases.

In executing the search within these databases, the initial focus was on identifying studies that explored how various forms of technology support equitable access to education. Search queries included combinations such as “digital technologies” AND “education equity and access”, as well as “ICT” AND “equitable education”. To further hone the results, additional filters were introduced by incorporating terms like “meta-analysis”, “position papers”, “policy papers”, and “systematic review”.

Of particular interest were meta-analyses that offered statistical insights into how digital tools impact education equity. These studies were especially valuable as they provided data-driven conclusions. The total number of results returned from each database is summarized in Table 1.

Table 1: Overview of Search Results Retrieved per Database.

Data base	Number of results
Education Data base	422
Scopus	23
ERIC	47
Web of science	6
Google scholar	136400

Screening Algorithm: The screening and inclusion algorithm is illustrated in Figure 1.

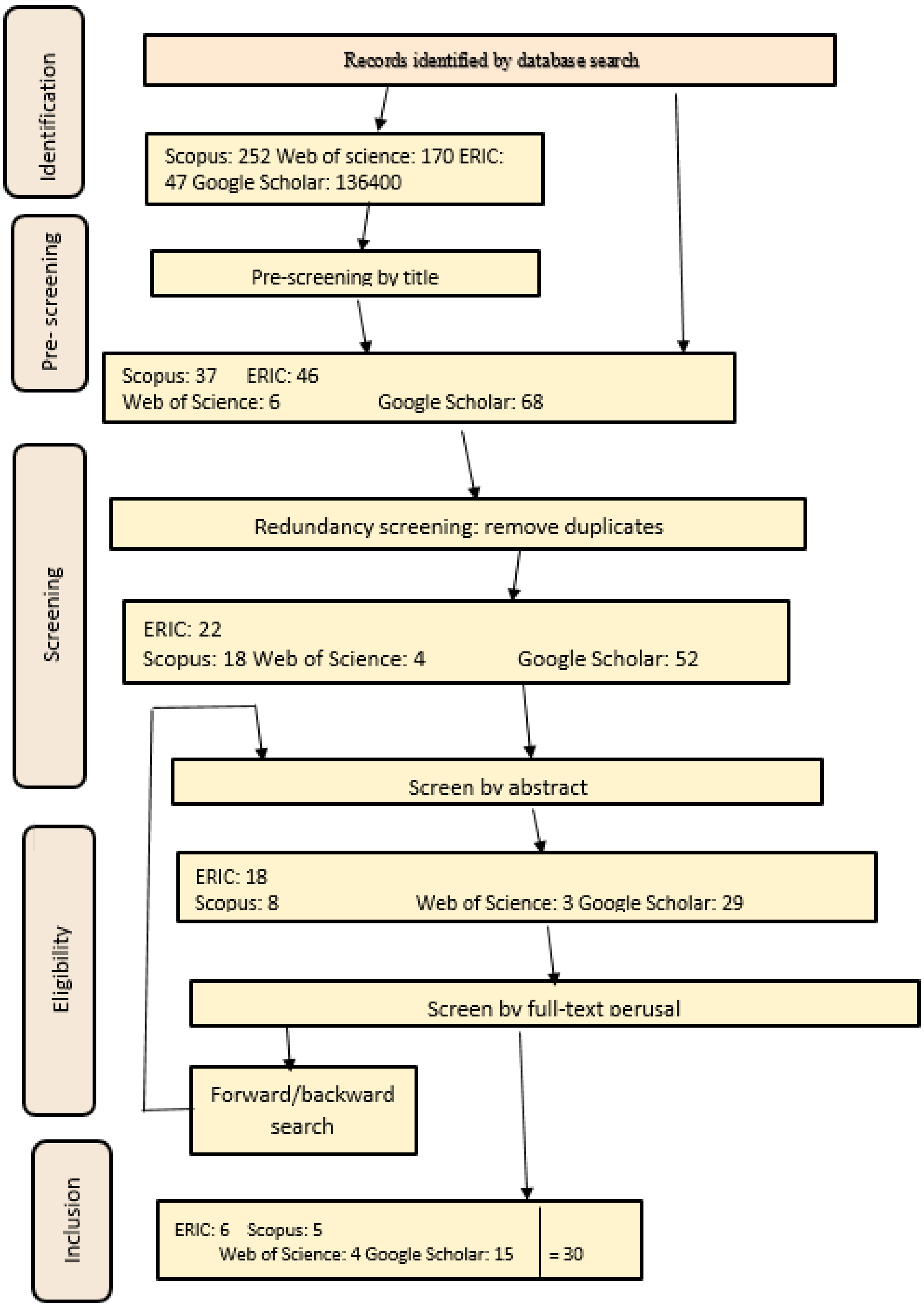

Figure 1. Screening process algorithm.

There was no application of filters based on the education level of participants; both undergraduate and postgraduate students were considered, spanning institutions such as colleges, universities, and vocational training centers. Additionally, the selection process did not involve restrictions related to the type of tertiary institution or geographical coverage. Given the overwhelming volume of search results obtained via educational databases and Google Scholar, a systematic pre-screening was implemented. This involved reviewing article titles to assess their alignment with the review's objectives. After that, duplicate entries were eliminated to avoid redundancy. Further screening of content was done using abstracts, followed by a full-text examination of the remaining studies. This full-text stage also included a snowballing approach—examining both referenced and citing works to identify additional relevant materials.

The literature searches employed databases like Google Scholar and various education-specific repositories using a range of keywords including "digital technology," "equity," "access," "equitable access," and "higher education." An initial pool of 136,869 documents was generated—136,400 from Google Scholar and 469 from education databases. Screening by title reduced the total to 157 documents. A deduplication step narrowed this number to 96. Further filtering through abstract review brought it down to 55, and then, through detailed examination of the full text, citation tracking, and consideration of publication status, the number was finally refined to 30 articles. Only those publications with a strong thematic connection to the use of digital technology in promoting equitable access to higher education were incorporated in the analytical phase.

III. Inclusion/Exclusion Criteria

We had a few criteria for an article to be included or excluded for the research. Table 2 shows the analysis of the eligibility criteria for inclusion and exclusion of articles for the research.

Table 2: Inclusion and exclusion criteria for the selection of resources on the role of technology in promoting equitable access to education in high institutions

Inclusion criteria	Number of Documents Included	Exclusion criteria
Published in 2010 or later	30	Published before 2010
Resources on higher education	30	Conference poster papers
Book chapters	3	Conference papers without proceedings
Reports from professional/international bodies	3	Resources on primary and secondary schools
Articles in English	30	Other languages
Peer-reviewed articles	7	Resources on pre-school education
Review and meta-analysis studies	10	
Position papers	4	
Policy papers	3	

During the preliminary filtering of entries from Education Databases and Google Scholar, inclusion hinged on whether titles or introductory excerpts incorporated terms like *digital technology*, *computers*, or *Internet*, or clearly aligned with the core research questions (RQ1–RQ3). For instance, studies with titles that referenced themes such as *educational equity* or *access* were allowed to proceed to the abstract screening phase. At that stage, 145 abstracts were assessed using exclusionary criteria; any study that evidently did not correspond with the research questions was omitted, resulting in 96 records advancing to full-text analysis.

To systematically examine and categorize these materials, a matrix was constructed. This organizational tool included a distinct column for each of the three research questions. Any section from a reviewed work that matched one or more questions was extracted and entered into the appropriate column. This allowed for a streamlined, comparative evaluation of the findings tied to each question. Ultimately, after analyzing all 96 full texts, the matrix featured 30 studies identified as offering substantial contributions to answering the specified review questions. These selected articles are listed in Table 3, where their relevance to individual research questions is clearly documented.

Table 3: Included work and their contributions to this review

Work	**Context**	**Theory**	**Research design, approach**	**RQ1**	**RQ2**	**RQ3**
Gray & Lewis, 2021	U.S.A	-	Mixed, Survey		√	
Edoru & Adebayo, 2020	Uganda	-	Mixed		√	
Jacobsen & Joyce, 2011	-	-	-			√
Ahuja, 2023	-	-	-	√	√	
Kaliisa & Picard, 2019	-	-	Descriptive			√
Liang et al., 2023	-	-	Quantitative			√
Gazi and Rahman, 2023	Bangladesh	-	Quantitative, Survey	√	√	
Abu et al., 2021		-	Systematic review	√	√	
Moore et al., 2018)	U.S.A	-	None	√		√
Cheung & Slavin, 2011)		-	Meta-analytic technique	√		
Lhamon, 2014	-	-	-	√		
Timotheou et al., 2022	-	-	Non-systematic review	√		
Joy, 2023	-	-	-	√		
Harle et al., 2021	-	-	Qualitative		√	
Bhan, 2011	-	-	Qualitative			√
Crystal Weise, 2o23	-	-	-			√
Kruppa, 2023	-	-	-			√

Menschel, 2011	U.S.A	-	-	√		
Higgins etal. , 2012			Meta-analysis	√		
Epshteyn ,2019	U.S.A	Innovation Adoption and Diffusion Theories	Quantitative	√		
Mann, 2023	-	-	-		√	
Marta Pinto, 2021	Portugal	-	-		√	
Sam Goundar, 2011		Grounded theory	Case study			√
Khazer et al., 2016)	-	-	Mixed		√	
Brown & Haupt	-	-	Qualitative		√	
Singh-Pillay	-	TPACK Model	-	-	-	√
Aldhafeeri & Male, 2015	UK		Quantitative		√	
Zheng, et al., 2016	-	-	-	√	√	√
Obura, 2010	-	-	Quantitative	√	√	√
GN et al., 2024	Zimbabwe	-	-	√	√	√

IV. RESULTS

The results are presented as a summary of the conducted research associated with each one of the posed questions.
RQ1: What is the role of computer availability in promoting education access and Equity in public higher institutions? Proposed role is listed in Tables 4. The most cited roles are improving education outcome, supporting diverse learning and bridging digital divide.

Table 4: Computer availability and equitable access to education

Role	Source
Bridging the digital divide	Moore et al., 2018; Gazi and Rahman, 2023; Higgins et al., 2012; Joy, 2023; Ahuja, 2023
Enhancing learning opportunities	Abu et al., 2021; Gazi and Rahman, 2023; Menschel, 2011; Ahuja, 2023; Zheng et al., 2016; GN et al., 2024
Supporting diverse learning needs	Abu et al., 2021; Gazi and Rahman, 2023; Timotheou et al., 2022; Higgins et al., 2012; Joy, 2023
Facilitating remote learning	Gazi and Rahman, 2023; Abu et al., 2021; Ahuja, 2023
Improving education outcome	Gazi and Rahman, 2023; Cheung & Slavin, 2011; Lhamon, 2014; Epshteyn, 2019; Higgins et al., 2012

The table 4 illustrates the multifaceted roles that computers play in promoting equitable access to education in higher institutions, and highlights the diverse reviewed literature through which the role of computers can be secured. It is evident that availability of computers significantly contributes to the leveling the educational playing field, particularly for students from underserved communities. By bridging the gap digital divide, computers enhance learning opportunities, support diverse learning needs, facilitate remote learning and improve education outcome hence promoting equitable access to education in higher institutions.

RQ2: What is the role of Internet availability in promoting education access and Equity in Education in public higher institutions? Proposed role is listed in Tables 5. The far most frequently cited role is enhancing academic performance of all learners and bridging the digital divide.

Table 5: Internet availability and equitable education

Role	Source
Bridging the digital divide	Khazer et al., 2016; Harle et al., 2021; Ahuja, 2023; Brown & Haupt, 2019; Abu et al., 2021; Gazi and Rahman, 2024; Gray & Lewis, 2021; Edoru & Adebayo, 2020; Obura, 2010
Facilitating access to a vast array of digital resources	Gray & Lewis, 2021; Edoru & Adebayo, 2020; Ahuja, 2023; Zheng et al., 2016
Accommodate diverse learning needs	Abu et al., 2021; Edoru & Adebayo, 2020; GN et al., 2024
Enabling remote learning	Gray & Lewis, 2021; Edoru & Adebayo, 2020; Zheng et al., 2016
Enhancing academic performance of all learners	Aldhafeeri & Male, 2015; Pinto, 2021; Gazi M. Alam and A. Rahman, 2024; Gray & Lewis, 2021; Edoru & Adebayo, 2020

Table 5 delineates the roles that the internet plays in promoting equitable access to education in high institutions, alongside the various sources of literature reviewed. The reviewed literature clearly emphasizes that equitable access to internet is fundamental in providing equal educational opportunities to all students, enabling remote learning, and facilitating access to a vast array of digital resources. As such, the role of the internet in promoting equitable access to education cannot be overstated.
RQ3: What is the role of smart phones availability in promoting education access and Equity in Education in public higher institutions? Proposed role is listed in Tables 6. The far most frequently cited role is also enhancing academic performance of all learners and bridging digital divide

Table 6. Articles reviewed about Mobile phones and education equity and access

Role	Source
Bridging the digital divide	Moore et al., 2018; Singh-Pillay, 2023; Goundar, 2011; Joyce, 2011; Liang et al., 2023; Crystal Weise, 2023; Moore et al., 2018; Kruppa, 2023; Obura, 2010; Zheng et al., 2016
Enhancing academic performance of all learners	Moore et al., 2018; Singh, 2023; Goundar, 2011; Bhan, 2011; Joyce, 2011; Kaliisa and Picard, 2019; Liang et al., 2023; Crystal Weise, 2023; Moore et al., 2018; Kruppa, 2023; Obura, 2010
Enhancing learning opportunities	Goundar, 2011; Liang et al., 2023
Accommodate diverse learning needs	Singh-Pillay, 2023; Weise, 2023; Zheng et al., 2016
Facilitate communication between educators and learners	Kaliisa and Picard, 2019
Support digital engagement	Liang et al., 2023; Zheng et al., 2016; Singh, 2023

Table 6 highlights the significant roles that smart phones play in promoting equitable access to education, along with the various sources through which their availability can be secured. It is evident that smart phones, with their affordability, portability, and connectivity, serve as indispensable tools in leveling the educational playing field. They enable students from diverse backgrounds to access learning resources anytime and anywhere, accommodate diverse learning needs, enhancing academic performance of all learners, facilitate communication between educators and learners, and support digital engagement. Consequently, ensuring equitable access to smart phones is a crucial step in fostering inclusive and equitable education for all students in higher institutions.

V. DISCUSSION

This section examines how digital technologies influence equitable access to higher education, emphasizing their transformative potential while also recognizing the persistent barriers to inclusive learning. According to Cheung and Slavin (2011), the integration of educational technologies within classrooms is expected to expand significantly due to increasing sophistication and affordability—echoing earlier research findings. However, the study emphasizes a notable gap in the volume of randomized trials, signaling a need for more rigorous empirical evaluations. As institutions welcome a growing population of learners with disabilities, enhancing digital accessibility has become a pivotal strategy for improving educational outcomes and addressing disparities in academic attainment.

Although higher education institutions have begun developing frameworks for digital accessibility, there remains a disconnect between these institutional commitments and faculty-level awareness concerning accessibility and disability support (Edoru & Adebayoa, 2019; Epshteyn, 2019). This gap limits the full participation of students with disabilities. Nonetheless, technological advancements offer new avenues for inclusive education by empowering students with special educational needs or language-related challenges to engage more meaningfully in academic life (Joy & Walker, 2023). Tools classified as assistive technology can foster educational equity by leveling the academic playing field.

In regions with limited infrastructure, such as underserved areas of Africa, internet and mobile network services are often scarce or unreliable, posing considerable challenges for accessing online educational materials (Mann, 2023). Information and Communication Technologies (ICTs), however, continue to support learning by fostering collaboration, autonomy, and the development of digital competencies (Pinto & Leite, 2020). Hands-on digital tasks, including coding and content creation, further exemplify the meaningful application of these technologies (Chase, 2024). The findings also reveal that income disparities exacerbate educational inequity, particularly in online learning contexts, where students from wealthier backgrounds enjoy better access to the necessary digital tools and stable connectivity (Abu Talib et al., 2021).

Despite these disparities, equitable access to educational technologies can serve as a mitigating factor in academic inequalities. It is essential for policymakers to promote access to such tools for all learners and educators, alongside providing targeted training to bridge digital divides (Gazi et al., 2024). Infrastructure issues—like bandwidth limitations that surface when large student populations attempt concurrent internet use—continue to pose technical challenges (Gray & Lewis, 2021). For instance, Makerere University has made strides in providing ICT infrastructure, yet gaps persist, necessitating alignment with international standards and adoption of emerging technologies (Edoru & Adebayoa, 2019).

The shift toward mobile teaching and learning demands capacity-building for both instructors and students, fostering innovation in the use of mobile platforms and enhancing cognitive development (Singh-Pillay, 2023). While Makerere University has articulated mobile learning priorities in policy documents, implementation remains inconsistent. There is an urgent need to revise and operationalize these policies to reflect current technological realities (Kaliisa & Michelle, 2019). Mobile devices can enrich learning experiences and promote inclusivity, but unresolved digital disparities must be addressed to prevent them from becoming exclusionary tools (Gottschalk & Weise, 2023). In lower- and middle-income settings, gender disparities in mobile access persist, with women frequently facing more pronounced barriers. This underscores the necessity for gender-responsive policies aimed at closing the digital gap (Kaliisa & Michelle, 2019). ICT-supported educational strategies have shown promise in expanding opportunities for girls, particularly through mobile learning platforms (Singh & Jain, 2017; Timotheou et al., 2023).

VI. LIMITATIONS OF THE REVIEW

An evident shortcoming in the majority of the reviewed literature is the absence of a clearly defined theoretical framework. Since theories serve as interpretive lenses in research, relying on findings devoid of such grounding may result in distorted interpretations. This highlights the imperative for a study framed within Social Equity Theory, to provide more analytical depth and contextual accuracy.

Most of the prior research employed either a qualitative or a quantitative methodology in isolation. This suggests the need for a dual-strategy design—integrating interpretative and positivist paradigms—to investigate the influence of digital technologies on equitable access to education within public higher education institutions. The synergy of both approaches enables more comprehensive data collection and minimizes the risk of overlooking critical insights. Another significant limitation stems from the geographical context of the literature reviewed. Much of the existing research originates from European contexts, making it less transferrable to Uganda due to considerable differences in digital infrastructure, governmental policies, and socio-economic realities. In fact, some of the sources lacked contextual grounding altogether, calling into question their reliability. These discrepancies reinforce the necessity for context-sensitive research that focuses explicitly on Uganda’s public higher education landscape.

Moreover, a distinct gap exists in the literature—none of the studies directly examined how digital technology supports accessibility and equity in higher education, particularly within public institutions. This omission creates a compelling rationale for a targeted study to fill that void. Policy documents reviewed also reveal systemic deficiencies. There are insufficient strategies to make digital tools and internet connectivity affordable across the student body. Furthermore, a lack of holistic policies aimed at establishing stable digital infrastructure—especially in remote and underserved regions—continues to widen the digital divide. Addressing these shortcomings requires a study that advocates for well-defined policies and regulatory frameworks to foster equitable digital access in Uganda’s higher learning institutions. Many of the position papers reviewed presented viewpoints rooted in specific institutional or individual perspectives. This inherent subjectivity limited the broader applicability of their findings. Therefore, there is a clear need for impartial, evidence-based research capable of informing inclusive, scalable solutions.

VII. CONCLUSION

In summary, computers are instrumental in facilitating equitable educational access by expanding learning modalities, promoting digital competence, and helping to narrow the gap between socio-economic groups. Nonetheless, unlocking their full potential depends on confronting digital inequities, securing the necessary technological tools, and enacting inclusive educational policies that accommodate all students. Doing so paves the way for a fairer and more inclusive educational environment for generations to come.

Similarly, the internet stands out as a transformative force in broadening access to higher education. Its provision of diverse academic resources, support for distance learning, and ability to connect learners across borders significantly contributes to leveling educational opportunities. Yet, to ensure this potential is realized equitably, it is essential to address infrastructure deficiencies, bridge the digital divide, and implement supportive policy frameworks that guarantee inclusivity. Smart phones, due to their mobility, cost-effectiveness, and internet access capabilities, have become vital in promoting education equity within higher institutions. Their widespread use allows learners from various socio-economic backgrounds to engage with educational materials at any time and location. Institutions can use this to foster inclusive learning environments. However, persistent challenges such as limited digital literacy and inconsistent infrastructure must be addressed to ensure all students benefit equitably from mobile learning technologies.

The integration of Information and Communication Technologies (ICTs) offers great promise in boosting academic achievement and reducing learning inequalities. However, regions with underdeveloped infrastructure still face serious obstacles. Overcoming these hurdles requires collaborative efforts by educators, policy architects, and stakeholders to guarantee equal access to ICT tools and proper training for both learners and instructors. Transitioning to mobile-based teaching and learning entails more than just offering devices; it demands targeted education and support, effective policy enforcement, and a sustained commitment to equity and inclusivity. By approaching these challenges holistically, academic institutions can unlock the full impact of mobile digital innovations, ensuring quality learning and lifelong opportunities for everyone. Strong cooperation in policy, implementation, and inclusive training is key to overcoming barriers and building a more just education system.

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Navigating the Decline: Analysis of Psychological Determinants of Student Engagement in Indian Higher Education

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ABSTRACT

Student engagement is a crucial determinant of academic success, influencing not only students' academic performance but also their overall satisfaction and retention in higher education. Recent trends in the Indian higher education sector, however, indicate a decline in student engagement. This decline raises significant concerns about the quality and outcomes of education in the country. This study examines the psycho-social and pedagogical challenges that contribute to the declining levels of student engagement within India's higher education sector. Drawing on data from a comprehensive survey of 1,750 students across 85 institutions, the research identifies several key factors influencing engagement. These include the widespread use of digital technology, the persistence of traditional teaching methods, and the escalating pressures of academic and socio-economic challenges. The findings report that only 10.9% of students reported feeling engaged during class sessions. This statistic underscores the urgent need for pedagogical reforms. The study further explores the dual role of technology in education. While essential, technology has also led to shorter attention spans and increased distractions among students. Moreover, the research highlights the critical role of interactive teaching methodologies, relevant course content, and instructor enthusiasm in fostering student engagement. The paper advocates for the adoption of experiential learning and innovative instructional strategies. These approaches aim to create more dynamic and inclusive learning environments.

Keywords: Student engagement; attention span; teaching-learning; technology enabled learning; higher education.

I.INTRODUCTION

Student engagement plays a pivotal role in the success of higher education institutions, serving as a critical indicator of academic outcomes [1]. It encompasses the degree of interest, motivation, and active participation that students demonstrate in their academic endeavors. Students who are highly engaged tend to perform better academically, complete their educational programs, and develop essential skills such as critical thinking and problem-solving. Despite its importance, there has been a noticeable decline in student engagement within the Indian higher education sector, raising concerns about the overall quality of education and student outcomes.

Engagement extends beyond merely attending classes or completing assignments. It involves active participation in the learning process, which includes engaging in classroom discussions, collaborating with peers, seeking assistance from instructors, and applying acquired knowledge to real-world scenarios [2][3]. High levels of engagement are associated with improved retention rates, enhanced academic performance, and greater satisfaction with the educational experience [4].

However, recent studies have highlighted a significant decline in student engagement across India. A research survey found that only 40% of students in Indian higher education institutions reported being actively engaged in their studies [5]. Similarly, the All India Survey on Higher Education (AISHE) revealed a increase in dropout rates, with over 20% of students discontinuing their courses before completion. These findings underscore the urgent need to address the issue of declining student engagement in the Indian higher education system.

II. LITERATURE SURVEY

The decline in attention span and student engagement has emerged as a critical issue in the educational sector, particularly within the context of the teaching-learning process [6]. A comprehensive study by McCoy (2020) identified the significant impact of digital distractions, specifically smartphones and social media, on students' ability to focus during lectures [7]. The research highlighted how frequent switching between digital devices and academic tasks leads to cognitive overload, ultimately impeding deep learning and student engagement.

Challenges in sustaining engagement are especially prominent in online learning environments. Research has shown that online platforms often struggle to hold students' attention, resulting in disengagement [8]. Factors such as limited face-to-face interaction and an abundance of online distractions were identified as primary contributors to this decline. Additionally, Wilson and Korn [9] explored attention span in traditional classrooms and discovered that students typically lose focus after 10-15 minutes of continuous lecturing. This phenomenon, termed "attention drift," was linked to the passive nature of lectures that do not actively involve students. Their study recommended interactive teaching methods to counteract this drift.

Sweller, Ayres, and Kalyuga [10] introduced the cognitive load theory, which posits that the human brain can only process a limited amount of information at one time. The authors found that presenting excessive information to students diminishes their attention span and reduces engagement. They suggested that instructional design should aim to reduce cognitive load in order to improve engagement. Additionally, Junco and Cotten investigated the effects of multitasking on academic performance, revealing that students who frequently multitask during lectures or study sessions tend to have lower grades and shorter attention spans [11]. They argued that multitasking hinders deep cognitive processing, resulting in superficial learning and disengagement from academic tasks.

Kahu [12] provided a multidimensional framework for understanding student engagement, which includes behavioural, emotional, and cognitive components. The study found that declining engagement often results from a misalignment between student expectations and the educational environment. This misalignment contributes to decreased attention and participation in academic activities.

In another study, Risko et al. examined the relationship between attention span and learning outcomes, concluding that students with shorter attention spans struggle to retain and apply knowledge effectively. The authors suggested incorporating frequent breaks and active learning strategies to help students maintain focus and enhance learning outcomes [13]. Similarly, Crosnoe, Johnson, and Elder [14] found that structured, interactive, and supportive classroom environments increase student engagement, while chaotic environments lacking clear expectations contribute to attention loss and disengagement. Fredricks, Blumenfeld, and Paris emphasized the importance of teacher-student interaction in fostering engagement, noting that positive and supportive teacher-student relationships are key to sustaining student attention and involvement in the learning process [15]. They recommended that teachers adopt a more personalized teaching approach to improve engagement.

Finn and Zimmer [16] conducted a longitudinal study on student engagement trends over several decades, revealing a steady decline. They attributed this decline to changes in educational practices, the growing use of technology, and evolving student expectations. The study underscored the necessity for educational institutions to adapt their teaching methods to align with contemporary student needs. A growing body of research documents the decreasing attention span of students and its impact on engagement [17] [18]. Studies suggest that the average attention span has decreased from 12 seconds in 2000 to 8 seconds in 2022, largely due to increased digital technology use [19]. This reduction in attention span is particularly concerning in higher education, where sustained focus is critical for deep learning.

The literature on student engagement in online and offline education presents mixed findings. Dhawan (2020) found that while online education offers flexibility and accessibility, it also presents challenges to student engagement due to distractions, a lack of interaction, and an unstructured learning environment. On the other hand, offline education, though more interactive, suffers from outdated teaching methods, large class sizes, and insufficient personalized attention. Previous studies reveal that the decline in attention span and engagement is multifaceted, with digital distractions, ineffective teaching methods, cognitive overload, and poor classroom environments all contributing to this trend. To address these challenges, educators must adopt innovative teaching strategies that meet students' evolving needs, enhance engagement, and improve learning outcomes.

III. Factors Contributing to Reduced Student Engagement

Multiple factors contribute to the declining levels of student engagement in higher education. These include the excessive use of technology, diminished motivation, ineffective teaching methods, and the growing pressures of both academic and non-academic responsibilities. The COVID-19 pandemic has further exacerbated these issues, as the abrupt transition to online learning has led to increased disengagement among students [20].

While technology has revolutionized education, it has also played a role in diminishing student engagement. The overreliance on digital devices and social media has been associated with shorter attention spans and heightened distractions. Moreover, the vast availability of information online can result in cognitive overload, making it challenging for students to concentrate on their academic work.

Traditional teaching methods, including lectures and rote memorization, often fail to engage today's students effectively. In many Indian higher education institutions, the curriculum is outdated and misaligned with students' interests and needs [21]. This mismatch between the curriculum content and what students find relevant can contribute to their disengagement.

The growing pressure to excel academically is another significant factor leading to decreased engagement. Students frequently face overwhelming workloads, which can result in stress, anxiety, and burnout. The prevalence of mental health issues among students is increasing, further diminishing their capacity to engage with their studies.

Socio-economic conditions also significantly influence student engagement. Students from disadvantaged backgrounds often encounter obstacles such as limited access to resources, financial difficulties, and familial responsibilities. These challenges can severely impede their ability to fully engage in their academic pursuits [22].

IV. Analysis of Psychological Determinants in Student Engagement

To establish a robust dataset for identifying factors that influence student attention and engagement, a survey was conducted among 1,750 students from 85 higher education institutions across India. The survey spanned the states of Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Telangana, and Maharashtra. The sample consisted of 74% undergraduate and 26%

postgraduate students, covering both technical and non-technical disciplines. The primary objective of the survey was to identify key challenges affecting student engagement and to explore strategies for enhancing engagement within classroom settings. The collected responses provide valuable insights into the factors that influence student engagement, the barriers that impede it, and the instructional methods preferred by students. This analysis aims to uncover the psychological attributes associated with these findings, offering a comprehensive interpretation that can inform educational strategies in Indian higher education.

The data analysis primarily focused on the level of engagement students experienced within their learning environments. The survey results revealed a significant issue: only 10.9% of students reported feeling engaged during class sessions. In contrast, a staggering 89.1% of students indicated disengagement, suggesting that current teaching methodologies may be inadequate in capturing students' attention or fostering active participation. This substantial lack of engagement highlights the urgent need for pedagogical reforms that can make classroom interactions more stimulating and interactive.

The survey identified key factors contributing to student engagement, with technology use (76%) and interactive teaching methodologies (71%) being the most influential. These findings underscore the importance of integrating digital tools and interactive approaches into the curriculum to enhance engagement. Instructor enthusiasm (42.3%) and the relevance of course content (41%) also emerged as significant, though secondary, contributors. These results indicate that student engagement is multifaceted, depending not only on the content but also on how it is delivered and the enthusiasm of the instructor.

Monotonous teaching styles were identified as the primary barrier to student engagement, with 72% of students reporting this as a significant issue. This suggests that traditional, lecture-based approaches may be failing to engage students who prefer more dynamic and varied instructional techniques. Additionally, 45% of students cited a lack of interest, likely stemming from unengaging teaching methods and irrelevant course content. The pace of learning (43%) also plays a critical role, with both too slow and too fast-paced instruction contributing to disengagement. A significant majority of students (78.9%) found numerical sessions more engaging than theoretical ones (20.1%), indicating a preference for classes that involve problem-solving and the application of concepts. This preference may reflect a desire for more practical, hands-on learning experiences.

The survey also examined the instructional tools commonly employed in the teaching-learning environment. PowerPoint presentations dominate the instructional landscape in Indian higher education, as reported by 93.7% of students. However, the effectiveness of PowerPoint as a primary instructional tool in fostering student engagement is questionable [23]. Other tools, such as multimedia (30.9%), group discussions (35%), and hands-on activities (22%), are less frequently employed, despite their potential to enhance engagement by accommodating diverse learning styles and encouraging active participation. A majority of students (73%) expressed a preference for offline, in-person classes, while 24% favored online learning, and only 3% opted for a hybrid approach. This preference for offline classes suggests that students value face-to-face interactions and the traditional classroom setting, which supports more direct engagement with instructors and peers. The relatively low preference for hybrid learning may indicate that, while it offers flexibility, it has not yet achieved the perceived effectiveness of fully offline or online modes.

The survey responses reveal several psychological attributes associated with student engagement in Indian higher education:

i. Preference for Interactive Learning: Students demonstrate a strong preference for interactive teaching methodologies and the use of technology, indicating a psychological inclination towards active, participatory learning environments that stimulate cognitive engagement.

ii. Need for Relevance and Instructor Enthusiasm: The importance of relevant course content and instructor enthusiasm suggests a psychological need for contextualized learning that connects academic material to real-world applications and for instructional delivery that is passionate and engaging.

iii. Aversion to Monotony: The high percentage of students reporting disengagement due to monotonous teaching styles reveals a psychological tendency to disengage from repetitive or uninspiring educational practices. This suggests that students thrive in dynamic and varied learning environments.

iv. Preference for Practical Engagement: The preference for numerical sessions over theoretical ones highlights a psychological inclination towards practical, problem-solving tasks that provide a sense of accomplishment and applicability.

v. Valuation of Traditional Learning Environments: The strong preference for offline learning environments underscores the psychological value students place on face-to-face interactions and the structured, immersive experience of traditional classrooms.

Looking ahead, student engagement in offline learning environments is likely to face ongoing challenges. The increasing reliance on technology, changing student preferences, and evolving educational models will necessitate more innovative and flexible approaches to teaching and learning. There may also be a growing emphasis on blended learning models that seek to combine the benefits of both online and offline education.

V. Possible Solutions to Enhance Student Engagement

To mitigate the challenges associated with reduced student engagement, it is essential for institutions to integrate technology in a manner that enhances rather than impairs engagement. This can be achieved by incorporating interactive learning tools, gamification strategies, and personalized learning platforms. Such platforms should be designed to cater to the individual needs of students, thereby fostering a more engaging and tailored educational experience. There is a pressing need for higher education institutions to revamp their teaching methodologies to make learning more engaging and relevant [24]. This could involve the adoption of experiential learning techniques, project-based learning approaches, and collaborative activities. These methods encourage active participation and help create a more dynamic and interactive learning environment.

Institutions must prioritize the mental health and well-being of students. This can be achieved by offering robust support services, promoting a healthy work-life balance, and shifting away from an overemphasis on rote learning and high-stakes examinations. These changes are vital for fostering a supportive educational environment that promotes overall student well-being.

Enhancing student engagement also requires the creation of inclusive learning environments that address the diverse needs and backgrounds of all students. This involves providing financial support, ensuring access to necessary resources, and fostering a sense of belonging within the student community. These efforts are crucial for building an educational atmosphere where all students feel valued and engaged.

VI. CONCLUSION

Student engagement is a vital determinant of the success of higher education institutions in India. The recent decline in engagement levels presents a pressing challenge that requires immediate attention. To counter this trend, it is essential for institutions to identify the underlying factors contributing to the disengagement and to implement innovative strategies aimed at revitalizing student involvement. The future trajectory of higher education in India hinges on the capacity of these institutions to adapt to the evolving needs and preferences of students, thereby cultivating an environment conducive to active participation and profound learning experiences.

Conflict of Interest

The authors declare that there is no conflict of interests.

Availability of data and material

This research employed data collection from 1750 students across 85 higher education institutions in India through an online survey. The data is confidential as it contains personal information and information related to the institutions and hence cannot be disclosed.

Funding for the research

The authors declare that they have no fundings to be disclosed for this research.

Acknowledgements

The authors would like to acknowledge all the institutions and the student community who participated in the data collection process.

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EXPERIENTIAL LEARNING THROUGH 360-DEGREE VIDEO: A POWERFUL TOOL FOR EDUCATORS

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ABSTRACT

STEAM (Science, Technology, Engineering, Arts, and Mathematics) education is at the forefront of innovation, and the integration of immersive technology is revolutionizing the learning landscape. This article explores the transformative impact of using 360-degree video as a powerful educator's tool to enhance experiential learning in STEAM education. 360-degree videos provide an immersive and interactive learning environment that allows students to step inside complex concepts, experience real-world scenarios, and actively engage with the material. The literacy of experiential learning includes Kolb's concept and immersive technology. Subsequently, it explores adopting the newest learning method with 360-degree technology to connect theoretical and practical knowledge efficiently, offering students a dynamic learning experience beyond traditional methods. A workshop was conducted for teachers, offering insights into the potential benefits derived from the utilization of 360-degree video for experiential learning. Faculty members appreciated the affordability and simplicity of creating Virtual Environment (VE) content, particularly through 360-degree videos. The ease of use enables educators to incorporate VR technology into their teaching practices without needing advanced technical expertise. Furthermore, it examines the challenges and considerations while implementing 360-degree video in engineering education, emphasizing the need for accessible technology, content relevance, and proper integration with curricular objectives. Using 360-degree video as an educator's tool represents a promising path toward enhancing student engagement, improving learning outcomes, and preparing future engineers to thrive in an increasingly complex and technology-driven world.

Keywords: *Experiential Learning, Immersive Technology, 360-degree videos, Virtual Reality, STEAM education*

I.INTRODUCTION

STEAM (Science, Technology, Engineering, Arts, and Mathematics) education is undergoing significant transformations due to the emergence of new technologies. The dynamic nature of engineering fields, with constant advancements and emerging technologies, challenges educators to keep the curriculum up-to-date and relevant. It is also essential to foster critical thinking, problem-solving skills, and collaborative learning to prepare students for the demands of a rapidly changing industry. There is a growing recognition of the need for practical, hands-on experience to align theory and application. There has recently been a growing emphasis on incorporating experiential learning opportunities, such as internships, projects and laboratory work (Berg Steiner, H., Avery, G. C., Neumann, 2010). Although the traditional methods of instruction are foundational, they need to be improved in preparing students for the multifaceted demands of modern practice. This realization has prompted educators, institutions and the higher education sector to explore and include innovative course content and delivery approaches. Specifically, they aim to leverage experiential learning and immersive technologies, like the augmented and virtual reality, across various disciplines to promote understanding, encourage student engagement and increase student satisfaction.

Virtual Reality (VR) content has become crucial in STEAM education, revolutionizing the traditional learning landscape. Engineering concepts, often complex and abstract, can be transformed into tangible, three-dimensional experiences through VR simulations. VR typically requires the leverage of a display, which is head-mounted and other sensory feedback devices to create an immersive experience (Le, Quang Tuan & Pedro, 2015). This technology has applications in various fields, including entertainment, education, and business, and it has the potential to offer users active and engaging learning that can be both entertaining and educational. The fully immersive VR solutions improve the user's motivation to learn, engage and enjoy several kinds of education and training contexts (Atsikpasi & Fokides, 2021).

Existing research has shown that VR technology allows students to engage in hands-on activities, manipulate virtual objects, and visualize intricate systems, fostering a deeper understanding of theoretical principles (Marougkas, A., Troussas, C., Krouska, A., 2024). Moreover, VR content is instrumental in addressing challenges such as safety training, as it allows students to navigate potentially hazardous scenarios in a risk-free virtual space. The versatility of VR also facilitates remote learning, enabling students to access realistic simulations and collaborate with peers in a virtual setting. Deeper learning may be made possible by the sense of presence that this immersion may produce (Chung, 2012; Falah et al., 2014). As industries advance towards digital transformation, integrating VR in STEAM education not only enhances the quality of training but also ensures guiding the graduates on the difficulties of modern engineering practices approach to preparing the next generation of engineers.

Despite these considerations, VR has struggled to attain broad acceptance and integration within the education sector. It is due to factors such as usability, lack of display or quality, motion sickness, and lack of accuracy in recognition (Noble, S.M, Saville, J.D. & Foster, L.L, 2022). Developing high-quality Virtual Reality content requires specialized 3D modelling, programming, and optimization knowledge. The technical complexity can be a barrier for content creators (Slater & Sanchez-Vives, 2016). The cost of creating VR content, including equipment, software, and skilled personnel, can be prohibitive. This challenge limits the usage of VR accessibility to a broader range of people (Chadwick, 2017). Some VR experiences may need help to provide realistic and intuitive user interactions, limiting the depth of engagement. Improving interactive elements is essential for enhancing immersion (Huang & Shah, 2018).

II. CONCEPTUAL BACKGROUND

EXPERIENTIAL LEARNING IN THE DIGITAL ERA

Experiential learning theory offers a comprehensive model where experience is central to the learning process (Kolb, 1984). The concept of learning through experience is not new. Aristotle, in 350 BC, remarked, "For the things we have to learn before we can do them, we learn by doing them." The experiential learning methodology was later refined and popularized by David A. Kolb, building on earlier work by educational pioneers such as John Dewey, Kurt Hahn, Kurt Lewin, and Jean Piaget.

Modern educators are adopting more effective teaching methods, with experiential learning standing out as a highly impactful approach. Research suggests that up to 90% of the skills required for today's knowledge-based roles are acquired through hands-on experience. Traditional lecture-style teaching, where an instructor addresses a passive audience, is becoming less relevant in an increasingly digital world (Johnson, C. D., 2018). By fostering active participation and immersive learning, educators can significantly enhance students' growth, equipping them with both theoretical knowledge and practical expertise. Figure 1 illustrates Kolb's cycle of experiential learning.

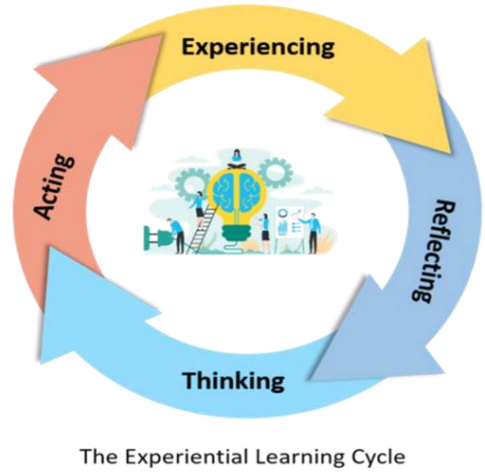

Figure 1. The Experiential Learning Cycle by Kolb

The educator conducts a hands-on, direct experience about the experiential life cycle, such as a lab experiment, field trip, or role-play, and then plans individual or group reflections. Understanding the event's significance is the primary goal of the conceptualization phase, which frequently involves reading or attending lectures on relevant topics. The next step requires learners to apply their knowledge to their personal and professional environments.

Education in the digital age has embraced continual evolution, integrating the numerous opportunities presented by technological advancements. Innovations such as remote and virtual laboratories, robotic systems, 3D virtual environments, augmented reality tools, sophisticated data visualization techniques, and mobile applications are transforming teaching methodologies. These technologies support approaches like problem-based learning, case-based learning, and online education. Collectively, they contribute to a more dynamic, student-centered approach, particularly in the field of engineering education (McGovern, Enda, & Moreira et al., 2019).

IMMERSIVE TECHNOLOGY

Immersion technology allows for the learning and refinement of new skills and practices by providing artificially manufactured digital settings and content that faithfully mimic real-life circumstances. Students receive the opportunity to be active participants who directly impact results rather than just passive viewers. It provides a risk-free, secure environment where learning may be replicated and achievement precisely quantified. It is learning through practice in which the only limitation is the sky (Argyriou, L. 2020 and Florian Wehking, M. W. 2019).

Immersive technology can revolutionize experiential learning by providing engaging and interactive experiences. Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) can develop realistic simulations that mimic real-life scenarios, allowing learners to actively participate and learn by doing (Jorge Alvarez, R. R. 2020). This hands-on approach enhances understanding and retention.

The different types of immersive technology provide unique benefits in several approaches in the education sector. These include:

Virtual Reality (VR) lets students immerse themselves completely in digitally created environments. Learners can navigate and interact within these virtual spaces using VR headsets such as the HTC Vive or Oculus Quest, often accompanied by headphones and hand controllers (Konstantinos Koumaditis, F. C., 2019).

Augmented Reality (AR), on the other hand, integrates virtual elements into the real world, creating an interactive overlay that blends digital content with the physical surroundings. This interaction is typically facilitated through smartphone applications or wearable smart glasses, allowing users to engage with the augmented environment in real-time.

Mixed Reality (MR) connects digital elements and the real world. Using the next-generation technologies related to imaging and sensing, MR can handle both virtual and physical items. MR helps see and immerse in the surrounding world and aids in interacting in a virtual platform using gestures via wearable glass like Microsoft Halo lenses (Lemonia Argyriou, D. E. 2016).VR, AR, and MR are examples of real and virtual worlds that fall under the general category of "extended reality" (XR).

360 degree - A small section of 360 content helps learners choose what they want to look from the photo or video with a mouse, controlling the viewing angle by moving their phone or trackpads (Alvita Ardisara, F. M. 2018). The experience is only partially immersive as it is watched on a computer or phone. With a headset or Head-Mounted Device (HMD), one can watch 360 content for a more immersive experience, but the video looks flat without feeling the depth. Most of the 360 videos are monoscopic. (Chareen Snelson, Y.-C. H. 2019).

3D-360 - 3D -360 employs stereoscopic techniques to create the illusion of depth, and the headset is used to watch the video to perceive the depth. Due to cameras made expressly to record stereoscopic footage, most 360-degree recordings are monoscopic. Three hundred sixty videos are higher in price. (Kyoungkook Kang, S. C. 2019). To enhance monoscopic 360-degree video and produce a stereoscopic version of a video with sensory depth, production skills, including extra 3D scanning hardware and software, such as Matterport or Cpix360, are needed.

VR Video - 360 VR and VR Video are practically synonymous. They speak about films recorded with specialised omnidirectional cameras allowing simultaneous 360-degree filming. Actual virtual reality must include an immersive component, which calls for using a headset. Providing users with mobility, or degrees of freedom (DoF), is a fundamental component of virtual reality. Three degrees of freedom, or the capacity to move the head around while consuming content, is 3DoF. Six degrees of freedom, or 6DoF, is the capacity to adjust the head and body position while interacting with material. Effective 360 or VR content attempts to strengthen the presence of the mind for the users, giving a realistic and natural feel (Ahmed Elmezeny, N. E., 2018).

Unlike computer-generated environments, 360-degree video is captured in real-life settings. These videos and images simultaneously record and display every angle, providing a comprehensive view. While this content can be accessed through VR headsets, immersing learners in the environment, their experience is limited to the filmmaker's perspective (Maria Grazia Violante, E. V., 2019). This means learners can look around by moving their heads but cannot interact with or navigate the environment independently, reducing interactivity. Nevertheless, 360-degree videos are an excellent way to introduce students to virtual field trips, construction site visits, and other experiences without requiring them to leave the classroom

III. LEVERAGE 360–DEGREE VIDEO IN STEAM EDUCATION

The role of immersive technologies, particularly 360-degree video, in STEAM education is pivotal in educating students to face the difficulties and demands of the current engineering environment (Shadiev et al., 2021). These immersive videos create authentic learning environments and offer multi-perspective viewing options (Shadiev et al., 2021; Rosendahl & Wagner, 2023). In surveying engineering education, 360-degree videos have prepared students for outdoor labs, improving their understanding of surveying methods and equipment operation (Bolkas et al., 2020).

Enhanced Immersive Learning Experiences

Headsets with cutting-edge display technology, superior processing power, and advanced sensors offer an unparalleled immersive experience. For engineering education, this means the ability to create highly detailed and realistic simulations of engineering environments, from construction sites and manufacturing plants to intricate machinery and systems. Students can virtually step inside a machine to understand its workings or walk through a construction site to learn about structural engineering principles without leaving the classroom (Lemonia Argyriou, 2017).

Interactive and Engaging Learning

The interactivity enabled by such advanced headsets transforms passive learning into an active exploration. Students can manipulate virtual objects, conduct simulated experiments, and test their designs risk-free. This hands-on approach deepens understanding and retains student engagement, making complex engineering concepts more accessible and easier to grasp (Shadiev et al., 2021). Studies have shown that 360-degree video content can increase student engagement, immersion, and motivation compared to traditional 2D learning methods (Kim et al., 2022).

Collaboration and Remote Learning

With the global shift towards remote learning, 360-degree headsets can bridge the gap between physical and virtual classrooms (Romain Christian Herault, A. L.-S. 2017). It enables collaborative projects where students can work together in a shared virtual space regardless of physical location. This fosters teamwork and communication skills, essential competencies for future engineers.

Accessibility and Customization

Educators might find it easier to create or access tailored 360-degree video content that aligns with their specific curriculum needs, making immersive learning more widespread and accessible (Johannes Sauer, J. S. 2017).

Real-World Application and Innovation

The benefits of 360-degree videos in education include increased learning motivation, authentic learning scenarios, immersive experiences, multi-perspective observation opportunities, and individualized learning (Rosendahl & Wagner, 2023). Students can apply theory knowledge in real-time by simulating real-world engineering challenges and environments, improving their problem-solving ability and readiness to work. Moreover, exposure to the latest technology trends inspires innovation and creativity, encouraging students to explore new solutions and technologies in their future careers.

Overall, 360-degree videos show promise as an effective tool for enhancing STEAM education and other disciplines.

IV METHODOLOGY

A 4-week course on Educational Media Production for E-Learning was held, in which a one-day workshop, “360-degree VR Immersive Content Creation for Educators”, was organised, focusing on the production of 360-degree videos and their visualization using Virtual Reality (VR) Head-Mounted Displays (HMDs). The workshop provided delegates with hands-on experience in creating immersive content, allowing them to explore the nuances of 360-degree video production. The workshop was attended by 32 teacher participants from 30 countries representing various ideologies and backgrounds. The workshop was well-received, with delegates gaining valuable insights into VR video production's technical and creative aspects.

During the workshop, teacher participants were engaged in hands-on training sessions to comprehend the process of creating 360-degree video content. Instructions were provided to them on the technical aspects of filming, editing, and producing immersive videos (see Fig.3). The process for creating a 360-degree Video for Experiential Learning is given in Figure 4. Additionally, teachers were provided with VR headsets to view 360-degree content, enabling them to experience the immersive environments themselves, as shown in the figure. Figure 5 is the image of the 360-degree video visualized by the workshop participants through the Virtual Reality headsets.

Figure.2. Participants learning how to film a 360-degree video

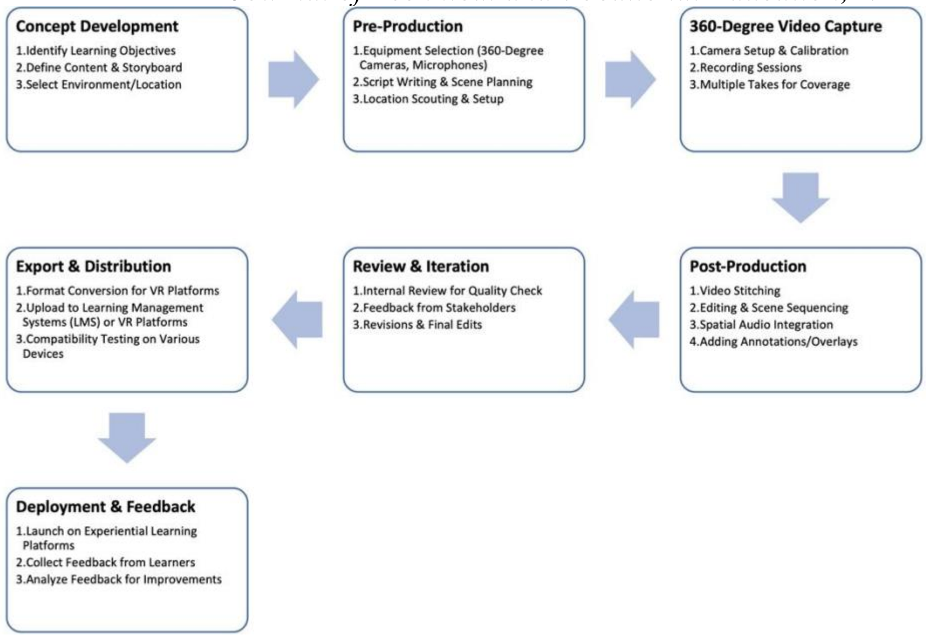

Figure 3. Creating a 360-degree Video for Experiential Learning

Figure 6. Participants wearing VR headsets to experience 360-degree video

Following the workshop, we gathered oral and written feedback from all teacher participants to capture their experiences and perspectives. The feedback revealed a high level of enthusiasm and acceptance among the attendees regarding using 360-degree videos as a tool for experiential learning.

Findings:

Cost-Effectiveness & User-Friendliness

- Participants appreciated the affordability and ease of creating VR content using 360-degree videos.
- Highlighted the potential of 360-degree Video through VR technology in enhancing education and training.

Preference for Short Videos

- Participants favored videos with a duration of fewer than 3 minutes.
- Shorter videos are more engaging and effective for learning.

Boost in Confidence

- Positive feedback encouraged participants to adopt 360-degree videos for immersive learning.
- Strong potential recognized for STEAM education, emphasizing experiential learning.

V. CHALLENGES AND CONSIDERATIONS FOR USING 360-DEGREE VIDEO IN EDUCATION

Integrating 360-degree video into educational practices presents unique challenges and considerations that span technological, financial, and pedagogical domains.

Technological Challenges

- Infrastructure Requirements: Schools need robust IT infrastructure, including computers with graphics cards, 360 Insta cameras for recording, and compatible devices for video editing.
- Technical Support and Training: Educators require training to create 360-degree videos.

Financial Challenges

- Equipment Costs: Recording and viewing 360-degree video requires specialized cameras, VR headsets, or compatible devices, which may strain educational budgets.
- Maintenance and Upgrades: Regular updates and maintenance of devices and software add to ongoing financial commitments.

Pedagogical Challenges

- Curriculum Integration: Embedding 360-degree videos into lesson plans requires careful planning to align with educational goals and enhance learning outcomes.
- Engagement vs. Distraction: While immersive, 360-degree videos may distract learners if not designed with a clear educational focus.

To overcome these challenges, a strategic approach involving investment in resources, training, and collaboration between educators and technologists is crucial. Thoughtful integration of 360-degree video can significantly enrich educational experiences and foster deeper engagement.

VI. CONCLUSION

Integrating 360-degree video in STEAM education represents a significant leap forward in experiential learning, offering immersive, interactive learning environments that bridge the gap between theory and practice.

Despite its potential, adopting 360-degree video and immersive technology faces technological, financial, and pedagogical challenges. These include the need for high-quality content development, hardware integration, curriculum alignment, and overcoming barriers related to cost and accessibility. Moreover, the effectiveness of these technologies in improving learning outcomes and student engagement necessitates further empirical research.

This paper emphasizes the transformative potential of 360-degree video in education while advocating for sustained innovation, research, and collaboration to address challenges and enrich the learning experience for future generations.

Acknowledgements

The author would like to sincerely thank **Prof. M. Manivannan** from the **eXtended Reality and Haptics Innovation Center (XTIC), IIT Madras**, for his invaluable guidance and support throughout the workshop and study.

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A Task Based Approach to Develop Presentation Skills: A Focus on Presentation Competence

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ABSTRACT

Enhancing English language teaching requires the use of diverse and effective methods that accommodate various learning styles, actively engage learners, and support language acquisition. This research paper explores the use of Interactive Task-Based Language Teaching (TBLT) pedagogy in ESL contexts, focusing on its transformative impact on language learning. This article outlines the theoretical issues underlying TBLT and its practical implementation in ESL environments. It also takes into consideration the challenges and opportunities adopted by such environments where English is not the dominant language. The research paper carried out research to examine the influence of Task Based learning and Teaching on acquiring language among a sample of 64 engineering under graduate students of G. Pulla Reddy Engineering College with English as a second language. A questionnaire was administered to all participants, encompassing questions related to their perceptions of the impact of task focused activities in improving presentation skills.

I.Introduction

Teaching any subject generally involves a study of subject's nature combined with the use of established teaching and learning principles often informed by research and psychological theories related to education. A resulting entity is what has been referred to traditionally as a method or approach to teaching, in which basic principles of teaching and learning are combined with appropriate classroom practices. Language teaching followed the same pattern and since the 1900s, the development of teaching methods has been a particularly dynamic area within the field. The professional status of language teaching was first reached during the twentieth century. In the early years of this century, applied linguists and others began to build on principles and techniques for the construction of teaching methods and materials. Stimulated by developments in linguistics and psychology, there first appeared a succession of theses proposing better and more theoretically sound ways of proceeding. The twentieth century saw unrelenting change, innovation, and sometimes divergent ideologies regarding the best way to teach languages.

Various frameworks for categorizing language teaching syllabi have been proposed including those by Yalden Long and Crookes (1992) and Brown (1995). Brown identifies seven main syllabus types: structural, situational, topical, functional, notional, skill based and task based (Jack C. Richards Theodore S. Rodgers 26). Theoreticians of communicative language teaching stress the use of activities with an "information gap" and "information transfer." Such activities presuppose working together on the same activity but each participant having pieces of information that others necessarily need for completing this activity. The concept of the "task" as a central activity in language teaching has undergone considerable development and refinement since it was first mobilized in the early phases of Communicative Language Teaching. TBLT is a language teaching approach that centers on using tasks as the foundation for planning and conducting lessons. This emphasis on tasks has been further endorsed by researchers in second language acquisition, who aim to create practical teaching strategies grounded in second language acquisition theory (Jack C. Richards Theodore S. Rodgers 2001).

The Importance of Presentation Skills within IT Firms:

IT companies, on many occasions, require their employees to present their ideas to colleagues, clients, and stakeholders. Presentation skills would range from project proposals to technical demonstrations. These could be a deciding factor in the success of the projects undertaken and collaborative ventures. The engineering student acquires these skills more confidently and early for his competitive advantage in order to achieve his goal of delivering information concisely and persuasively. These deficiencies in practical communication skills are often because teaching methods in schools have remained theoretical. Task-based teaching bridges this gap by providing students with hands-on experiences that mirror workplace scenarios.

II. Research Framework

This research used a quantitative approach to evaluate the role of TBLT in improving language and presentation abilities among undergraduate students in engineering. The study intended to test whether the TBLT methodology was effective for teaching communicative skills, specifically in the framework of teaching and learning English as a second language.

Study population and respondents

Sixty-four undergraduate engineering students from G. Pulla Reddy Engineering College could represent a wide variation in proficiency in English because the college is a representative sample for various strata in the society. "These undergraduate students were targeted deliberately since they are in the EFL learning environment, hence the suitable batch to test the effectiveness of TBLT regarding language acquisition and presentation skills." The participants were enrolled in their regular Soft Skills lab which is part engineering curriculum in their III semester which English is used as the medium of instruction for all courses both technical and non-technical.

Data Collection Instrument

In this direction, a structured questionnaire was designed and administered to learn the effectiveness of TBLT in enhancing their presentation skills. The questionnaires were both closed-ended and Likert-scale. The closed-ended questions were used to assess those considered specific to the task-based activity: its contribution to language proficiency, confidence, and presentation abilities.
Responses on the Likert scale spanned from strongly disagree to strongly agree offering a clear understanding of participants' attitudes towards the intervention.

Procedure

The intervention was performed in a classroom environment and was incorporated into the students' regular curriculum of language and communication skills. The treatment task-based activities aimed at enhancing presentation skills were conducted for six weeks. Activities included the following:

Presentation by Individual/Group: The students prepare and present on both technical and non-technical topics, mirroring the professional settings of such presentations.

Feedback sessions: Several issues that needed attention were thereby highlighted through constructive feedback from peers and instructors alike and often refined.

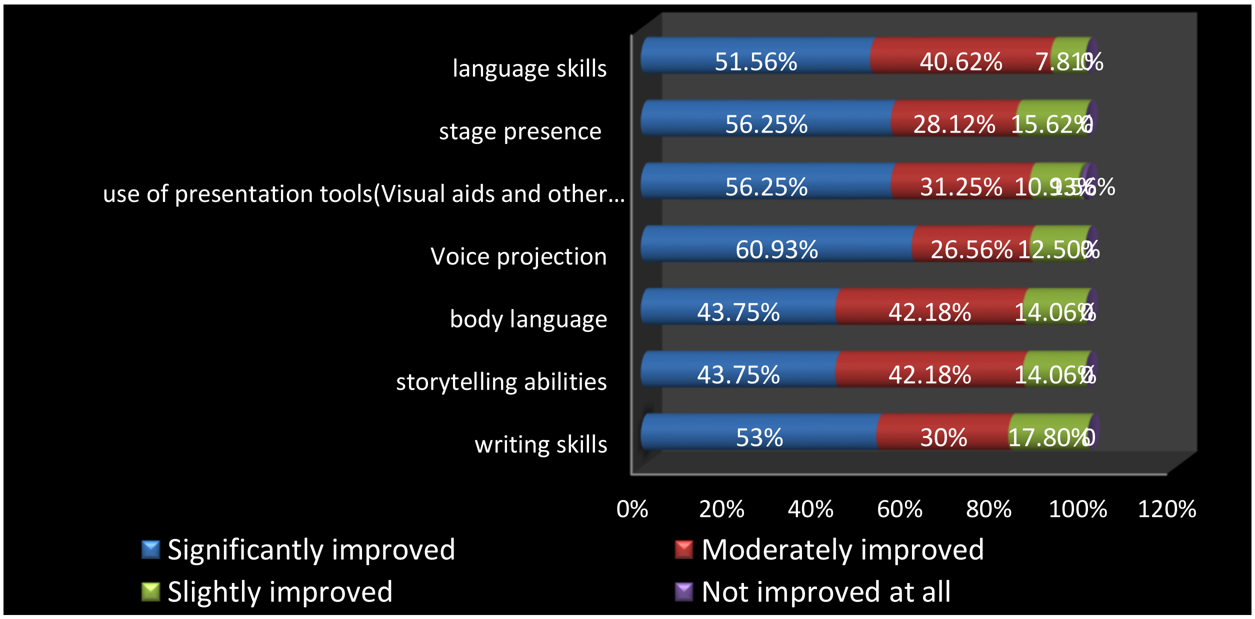
These interactive activities included role-playing, case studies, and collaborative problem-solving activities that enhanced teamwork and active participation.

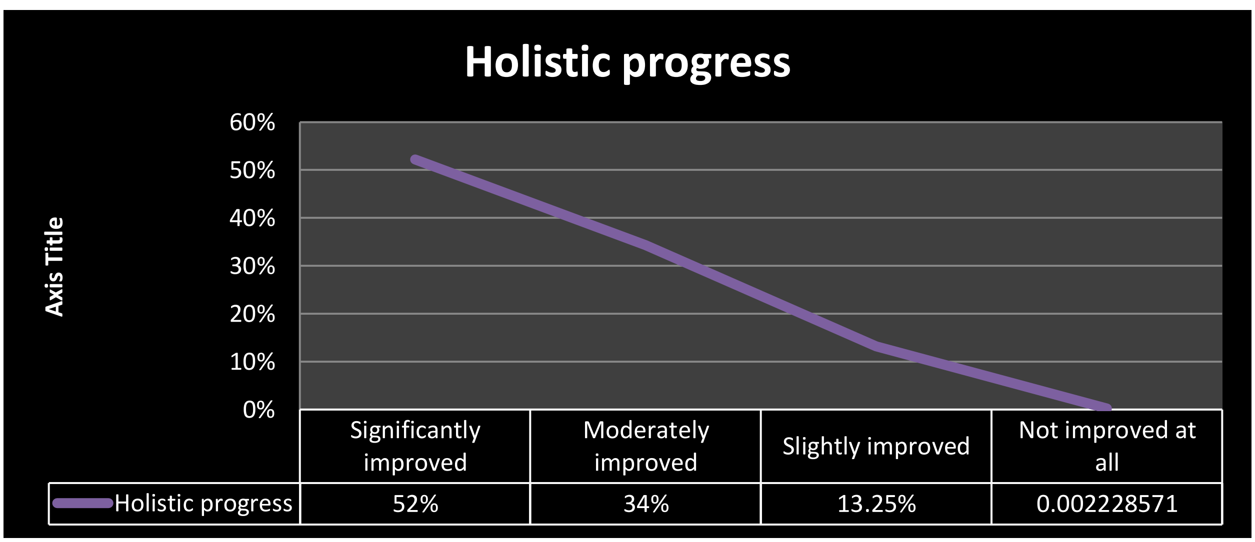
Employing the use of multimedia tools

Students utilized visual aids like PowerPoint slides and employed digital tools in making presentations. Following these, the questionnaire was used to ascertain students' perceptions and self-report gains in skills like the use of language, stage presence, voice projection, and storytelling.

III. Data Analysis

Descriptive statistics on the data collected were performed, showing the degree of perceived improvement across multiple presentation skills. Specifically, the percentage of students showing large, moderate, or small improvements was calculated and visualized as a series of graphs to highlight the impact of TBLT on their learning outcomes. Subsequently, it compared these results against one another from various skill categories in search of patterns and areas of strength.





Results:

This study is aimed to examine the impact of TBLT on enhancing presentation skills among engineering students. The data were gathered from 64 respondents through the administration of a structured questionnaire measuring perceived improvements in their presentation capabilities. These responses were then rated on a four-level scale: "Significantly Improved," "Moderately Improved," "Slightly Improved," and "Not Improved at All." Descriptive statistics computed include the mean, median, mode, range, and standard deviation.

Descriptive Statistics
Significantly Better: 50% (32 participants)
Moderately Improved: 34% (22 participants)
Slightly Improved: 13.25% (8 Participants)
Not Improved at All: 0.0022% - (1 participant)

Mean	Median	Mode	Range	Standard deviation
24.81	23.625	50	49.997	23.5

IV. Findings

Significant Improvement

Fifty percent of them also responded that TBLT significantly improved their presentation skills, underlining the potential of task-based activities to bring noticeable development in these aspects: language use, stage presence, and confidence.

Moderate Improvement

A full 34% then reported moderate improvement. Such individuals probably benefited from the activities but perhaps needed more practice or individualized support to achieve the higher levels.

Slight Improvement

Well, smaller-sized gains were realized by the smaller group of students, 13.25%. It would thus appear that while TBLT activities proved helpful, their effectiveness might vary depending on individual factors such as initial proficiency levels or engagement.

A minimal lack of improvement

Only one participant reported no improvement, and that accounted for findings equating to 0.0022%, indicating the near success of the intervention for the majority of the cohort.

The results indicate that TBLT is an extremely effective method for improving the presentation skills of engineering students. Since both mean and median values were within a range of moderate to significant benefits, it logically follows that the variation was relatively small. The standard deviation of 23.5% indicates that even though there was some diversity within different levels of perceived improvement, most of the students gained substantially. The reliable positive effects in both categories of "Significantly Improved" and "Moderately Improved" demonstrate the pragmatic and entertaining nature of TBLT, hence making it more focused on the requirements that students are likely to know in a real professional world. These findings point toward the fact that inclusion of task-based methodologies into the practice of language teaching could grant students communicative skills necessary in their future profession.

Conclusion

The results, therefore, show that TBLT is effective in developing the presentation skills of engineering students. The statistical evidence is solid to support this effect, as the overwhelming majority of participants reported making great progress. Long-term benefits could also be examined in further research on TBLT and its use in various contexts of learning. The research methods followed all ethical protocols and guarantees that no integrity distresses in the study. Participation was strictly voluntary; furthermore, students were informed of the purpose of the research. Anonymity and confidentiality of responses were maintained throughout this study. An instructor made sure these research activities did not interfere with any requirements set forth by the students' academic needs. This methodology illuminated how TBLT influences ESL learners to develop their presentation skills in the context of engineering education.

Limitations

1. Sample Size and Diversity
Present research is based on a very limited sample of only 64 students from one institution, namely G. Pulla Reddy Engineering College. Such a limited sample may limit the generalizability of the findings from this study to other institutions or contexts. A more inclusive sample would yield broader insights.

2. Self-Reported Data
The main method of data collection was subjective responses through a questionnaire. This approach gives perceptions but does not usually indicate the actual improvement of presentation skills due to several biases such as overestimation and underestimation of progress.

3. Absence of control group:

No control group was included in this study to contrast the effects of TBLT with those of traditional instructional methods.

4. Concentrate on Certain Skills
This study primarily focused on presentation and communication skills; hence, other aspects of language acquisition, such as writing, listening, and reading skills, could not be fully developed.

5. Constraints on ESL Context
The study was conducted in an ESL environment; therefore, generalization of findings is limited to EFL or native-English-speaking settings.

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Professional Development Practices in Teacher Education Infusing AI: A Professional Development Practices in Teacher Education through Wenger's Communities of Practice

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ABSTRACT

Teaching is a dynamic field which requires constant learning and upskilling to ensure that the educators are well equipped and aware of the evolving classroom environment, and technologies. Teacher education requires continuous professional development practices for an effective outcome in student's learning and progress. This research paper focuses on the effectiveness of professional development programs in teacher education, emphasizes on their significance, theoretical foundations, challenges, and future directions. This study is built upon a key learning theory like Wenger's communities of practice to highlight the importance of lifelong learning among teachers. This research paper examines the current professional development programs in equipping teachers with the necessary skills to integrate AI driven learning and emerging educational technologies into their teaching practices for their future direction. This study examines various models of professional developments such as formal programs, workshops, seminars, webinars, mentoring, online courses, peer observations, Faculty DPs and PDPs with a focus on their effectiveness in enhancing teacher's instructional skills and student's outcome. Challenges such as institutional constraints, workload issues, and resistance to change are identified as barriers to effective professional development. This research paper highlights the need for sustained, research informed, and contextually relevant professional development programs that ensures the continuous growth of educators and the overall improvement of teaching and learning.

Keywords: *Professional Development, Teacher Education, Classroom, Technology, AI, Communities of Practice.*

I. INTRODUCTION

Teaching is not just a job where you learn, qualify and take up the position to teach, it requires continuous learning, and learning agility to sustain, and to infuse progress within the student. The knowledge and exposure a batch has when a teacher teaches in 2025 will not be the same when she teaches a different batch in 2030. Within these 5 years of time, students change, their exposure to technology changes, their accessibility to knowledge changes, their skills, and competent level changes. By 5 years, the teacher has to deal with an entirely different generation, with different capabilities and skills. To make the teacher community well equipped to the evolving classroom setting, there is a need for adapting to technology infused learning. To deal with the changing generations of students, there is a need for upskilling the teachers and it is achievable only through proper professional development programs. These programs are offered in different modes such as FDPs, PDPs, workshops, seminars, webinars, etc. But the real question is, do these professional development programs really coincide with the current evolution in the educational system, and student's learning? seminar papers and projects. How do teachers evaluate these kinds of work done by a These days, students are very much aware and good at using AI to create their assignments, student? How do we check the authenticity of these works? A teacher has to be well equipped and aware of the technology to check the originality of a work to have a fair evaluation due to the evolving and emerging AI technology in education. But how do we upskill and professionally help these teachers grow? It is achievable only through relevant Professional development programs that help teachers to sustain, upskill and equip them to face the evolving educational trends and students for a better learning and outcome. This study focuses on proving that a professional development program is more effective when we incorporate Wenger's *communities of practice* while designing programs for teachers. The significance of this paper focuses on improving the quality of education in accordance with the evolving technology for a better learning, and outcome among the teachers.

Wenger's Communities of Practice (CoP) - Overview

Etienne Wenger along with Jean Lave introduced the concept of Communities of Practice in their 1991 book called *Situated Learning: Legitimate peripheral participation*. The idea of communities of practice was later developed into Wenger's solo work called *Communities of Practice: Learning, Meaning, and Identity* in 1998, he found that learning is not just an individual activity but a deeply social activity that is rooted in shared experience, and interaction. A community of practice is defined as a group of people who share their concern, a set of problems, and passion about a topic to deepen their knowledge and expertise by an ongoing interaction.

Objectives of this study:

- To ensure continuous learning among the educators to face the evolving classroom environment and education.
- To equip the educators and prepare them for AI infused teaching and learning.
- To explore the role of Wenger's CoP in supporting the effective implementation of professional development strategies.

II. LITERATURE REVIEW

Professional development programs have long been considered as a critical part in improving the teacher's teaching quality, and students' outcome. Traditional PD programs often involve short term workshops or lectures, which lack sustained engagement and practical application. Researchers have constantly emphasized on the need for an ongoing, collaborative, and contextualized PD practices that would encourage teacher-reflection, peer learning, and real world relevance for a better learning. (Wenger, 1998; Lieberman & Mace, 2010)

A model that has gained attention in recent years is Wenger's Communities of Practice (CoP). Wenger outlines that an effective learning takes place within communities when the members share a common domain, engage in regular interaction, and build a collective practice through shared experiences, and problem solving. In the context of teacher education CoP offers a framework for sustained professional learning, where teachers support each other, exchange practical insights, and co-create teaching strategies (Wenger & Snyder, 2000).

In India, the need for improving the PD programs is visible through platforms like DIKSHA, while some initiatives to support peer learning, and teacher networks were led by British Council, but still many programs still rely on passive, one-time training sessions with limited follow up or contextualization. Furthermore, global research discusses the integration of AI in education, there is limited literature exploring how AI can be meaningfully introduced in professional development programs for teachers, especially in government institutions across India.

Teachers are expected to evaluate AI generated student work, and integrate tools like ChatGpt, Grammarly, or any AI tools in their instruction, but many educators are hesitant and need training in navigating these changes in education. As the education system evolves towards an AI driven classroom environment, the professional development programs should evolve as well, not only to enhance skills but to maintain pedagogical integrity and fairness.

RESEARCH GAP

Professional development programs are widely considered as a cornerstone in equipping teachers with the evolving trends in education but most of the existing research focuses on conventional PD approaches such as short term workshops, formal training sessions, and top-down knowledge delivery. These models often lack sustainability, relevance and practical applicability in today's evolving educational environment, particularly as today's classrooms become increasingly influenced by emerging technologies like Artificial Intelligence.

In recent times, AI integration in education has gained humongous attention, most of the research surrounding AI in education focuses on student's learning outcomes, data-driven personalization, and institutional level infrastructure. Only a limited study has contributed to examine the preparedness, and struggles of teachers to integrate AI tools in their teaching practices. This has created a significant disconnect between technological advancement, and teacher preparedness.

PD initiatives such as FDPs and PDPs do exist in context but these often do not include comprehensive modules on AI literacy, ethical consideration in AI use, and AI tools in classroom application. Most PD frameworks do not consider teachers' varied comfort levels, access to resources, need for continuous peer support, particularly in government institutions, and less urban settings where digital exposure can be limited.

Despite the growing popularity of Wenger's Communities of Practice (CoP) as a framework for collaborative and experiential learning, its application within formal PD programs especially at equipping teachers to use AI remains underexplored. Current literature does not address much on how to integrate CoP models into PD programs to foster deeper engagement, sustained learning, and shared problem solving among educators in navigating evolving technological changes.

When it comes to Indian context, this research gap is more pronounced, as most PD programs, and AI initiatives are policy driven but lack grass-root level insights from the educators who are directly affected by these changes. This research aims to bridge the gap by offering a bottom-up perspective by gathering real data from teachers by assessing their needs and perceptions to propose a CoP based model that aligns with technological innovation and practical teaching.

RESEARCH QUESTIONS

1. To what extent do the current professional development programs align with the technological and pedagogical need of teachers in an AI driven educational environment?
2. What are all the challenges teachers face while adapting to AI infused learning environments, and how can professional development programs address these issues?
3. What are teachers' perceptions about the existing professional development programs in helping them deal with the AI generated students output?
4. What strategies can professional development programs implement to ensure teachers remain agile, and competent in technology infused classrooms over time?
5. How can Wenger's communities of practice be integrated while designing more effective professional development programs for teachers?

This research focuses on how professional development programs can evolve to meet the demands of AI infused education, this topic is still emerging in teacher education studies. Educators are aware of AI's role in education but there is limited research that connects AI integration with teacher training PD programs especially within the Indian context. One of the key contributions of this research paper is the integration of Wenger's Communities of Practice as a framework to design PD programs to make it more effective, and impactful. This research is advocated for ongoing, peer-based, collaborative learning models that reflect how teachers grow through sharing, reflecting, and doing things together. This theoretical lens adds a fresh perspective to current PD programs, showing how communities of educators can co-construct knowledge, and supports each other in adapting to rapid technological change. In short, this research paper stands out by bringing together technology, teacher development, and reconstructing PD programs through theory in a way that is practical, relevant and forward thinking. This study not only just critiques what is lacking, but also it suggests some solutions that are meaningful, sustainable, and teacher centered in the age of AI.

III. THEORETICAL FRAMEWORK AND RESEARCH DESIGN

This research focuses on using Wenger's Communities of Practice (CoP) to create structured professional development programs to incorporate AI in education for an effective outcome. The term Communities of practice is originated from Jean Lave and Etienne Wenger in 1991 from *Situated Learning: Legitimate peripheral participation*. Wenger's Communities of Practices can be very effective in the process of learning and practicing it practically. It focuses on three characteristics such as Domain, Community, and Practice.

The domain: It is not just a casual group or social network; it consists of members with shared interest on a particular topic or domain. Everyone in this group is committed to their interest or topic. This shared commitment among these people talks about their shared competence or knowledge in that particular area, this shared knowledge and competency separate them from the outsiders. The domain doesn't have to be formally recognized as expertise by the society for example, a youth gang may not be seen as experts by the society but within their gang they may have developed some survival skills, building trust, and maintaining their identity. They learn from each other, and value what they know. The community of practice is held together by a shared domain of interest or challenge. This domain creates a sense of belonging, shared learning, and identity even if outsiders don't consider it as formal expertise.

The Community: A community forms through interaction, and shared learning, members of a CoP don't just share the same interest or domain, they also actively interact with each other. They discuss, collaborate, exchange ideas, and help each other through these interactions and relations. They learn together, build trust and connection. A group of people who go to school together or work together doesn't form a community of practice. These people may study together in the same classroom or work together in the same office with the same designation, but unless they interact to share their knowledge, and grow together they don't form a CoP. A website or forum where people don't truly engage with each other is also not a CoP. When it comes to forming a community, physical closeness or daily work isn't required, what matters is intentional interaction and learning. Let's take two painters as an example here, they both don't meet often and work together, but whenever they meet, they critique each other's work, they share their knowledge with each other, they give suggestion to each other to improve each other, and develop new ideas together, this behavior makes them a CoP. A real community is formed when people with common passion or problems come together to help each other and learn together.

The Practice: In a community of practice, members are not just talking, they are doing stuff. It is not just about shared interest, a CoP is more than just a group of people with shared likes, and interests like loving a specific movie or books, It is beyond that. It is a group of practitioners who actively do something, and share experience related to their work or practice. While practicing something it needs shared resources, and experience. Over time, these members build a shared repertoire by sharing their common experience with each other, sharing their stories, and the lessons they learned from it, tools, strategies, and techniques they used while facing challenges and ways to solve problems that come up regularly indicates CoP. This shared knowledge with each other is what defines their practice. A quick interesting conversation about taking care of a patient with a teacher doesn't make up a CoP because obviously a teacher is not going to practice it at a hospital, but the same conversation with a nurse or a doctor can be useful to them in practicing it, this can be called CoP. Practice can be both formal and informal. A professor creating a research article to document what they've learned can be taken as a formal practice, and a group of nurses who meet casually for lunch, and share stories and tips that would help other nurses in handling their patients can be taken as an informal practice. These people don't even realize that they are forming a community of practice. For a group to be a community of practice they must actively engage in a shared work or a profession and through ongoing interaction they build a collective knowledge base. It is not about liking the same thing; it is all about doing, sharing, and growing together as practitioners over time.

These three elements form a community of practice and it focuses on problem solving, request for information, seeks experience, reuses assets, builds arguments, coordination, discusses new ideas, identifies gaps in competence, and documents data. Community of practice is called by various names such as tech clubs, thematic groups, learning networks etc. These groups come in different forms such as small groups, large groups, online groups, face to face groups, global groups, and some are formally recognized while some are informal and not recognized. Communities of practice has long been from the start of humans on this earth. In most of the cases, people don't even realize that it is a Communities of practice, because it happens in a natural, and organic way.

The concept of communities of practice can be applied to various sectors like Education, Government, professional association, development projects, teacher training, etc. Let's focus on the concept of CoP in Education, and professional association to understand how it can be used in designing professional development practices in teacher education. Wenger emphasizes that teacher training is one of the earliest, and most effective applications of communities of practice within the education sector. Teachers are not just knowledge deliverers, but also practitioners who constantly develop skills, strategies, and insights through real classroom experiences. Traditional teacher training often focuses on one- time workshops, but CoP offers something deeper, ongoing, peer based learning grounded in real life experience.

Many teachers and schools, especially in rural areas are isolated which can be seen as a barrier to growth. CoP breaks this barrier by allowing them to interact with teachers from different places, and foster learning and growth. Just like students, teachers learn best when they actively participate instead of remaining a passive recipient. In most of the professional development programs it focuses on teaching the new techniques to the teachers, but it fails to train them practically on how to use the technique. CoP encourages teachers to be co-learners and co-creators of knowledge. Wenger believes that effective teacher training must go beyond formal instruction; it should involve sustained collaborative practice where teachers grow by engaging with peers, reflecting on real world experience, and developing a shared repertoire of knowledge that evolves over time.

IV. METHODOLOGY

This study uses a quantitative descriptive research design to analyze the current status, and effectiveness of professional development programs in training educators to incorporate AI in their teaching practices. Data was collected through a structured Google form survey, specifically designed to analyze educators' experience, opinion, and ease in adapting to AI enhanced classroom setting. A total of 24 educators have participated in the survey. Participants were selected using purposive sampling, this survey targeted college- level teachers across various disciplines. The majority of the participants are from government colleges in India, with varying years of experiences with subject expertise. This approach helps us to understand how educators from a diverse background perceive, and adapt AI technology in their teaching. The survey instrument consists of a mix of close ended questions, aimed at gathering quantifiable data.

V. DISCUSSION

A group of 24 educators from various cities have participated in this survey. They all handle different subjects for college students, and most of these educators are from government colleges with years of experience from the collected data. By analyzing the collected data, most of these educators feel that the professional development programs need improvement and proper hands-on training to use and incorporate AI in evolving classroom settings. The age range of the participants ranges from 23 to 59 which can be seen in the chart 1.1. They are all from different Indian cities like Visakhapatnam, Chennai, Erode, Karaikudi, Tirunelveli, Tenkasi, Dharmapuri, Madurai, Tuticorin and Rasipuram as shown in the chart 1.2

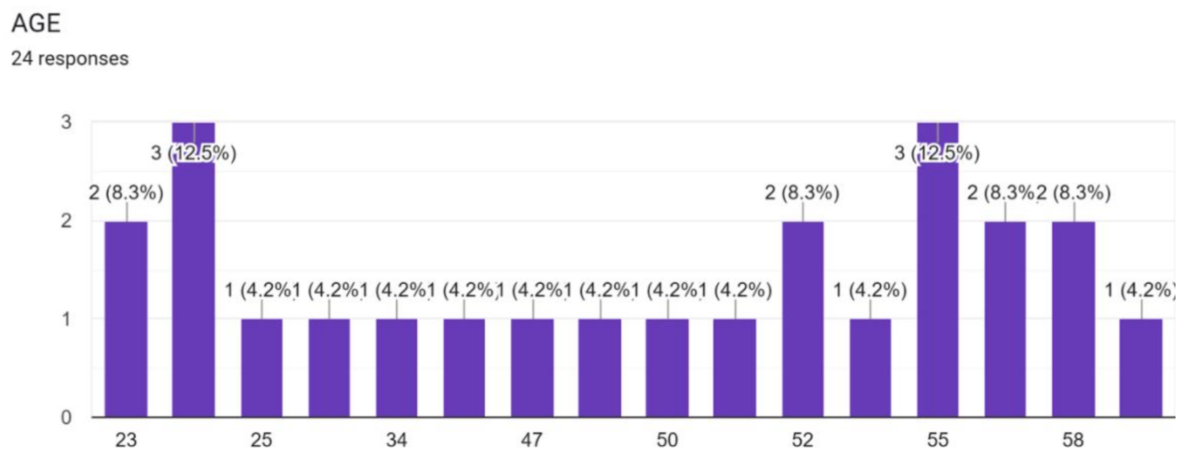

Figure1. Demographic Details - Age

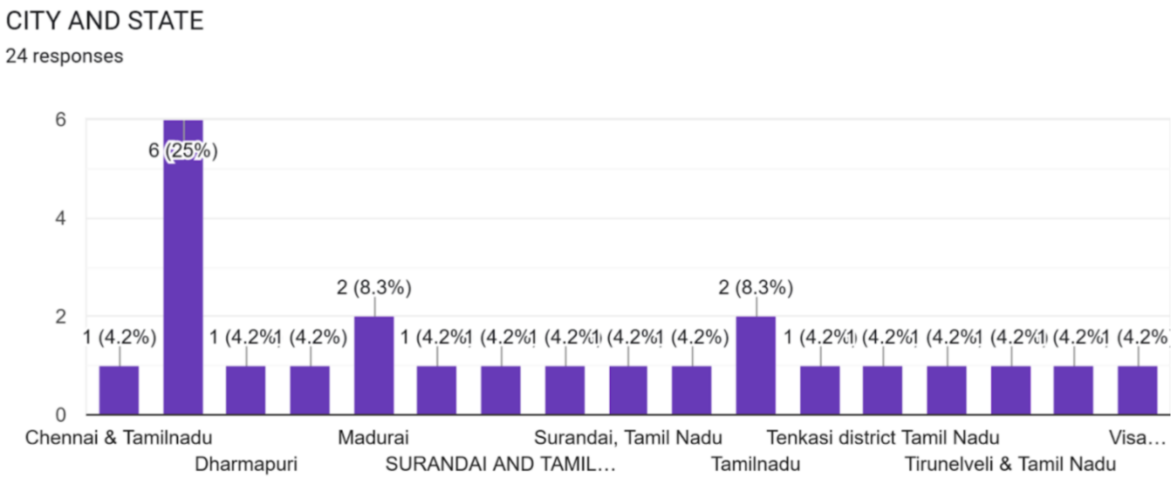

Figure 2. Demographic Details – City and State

The given figures, and graphs represent the current status of professional development programs in infusing AI in teaching. The root cause of solving an issue is to find where the problem lies. Based on this small survey, the majority of the educators are ready to adapt to the evolving classroom environment and infuse AI technology into their teaching and related assistance. It is evident that they have heard of many AI tools that can bring revolution in the education system, about 50% of these educators use AI for their teaching and related assistance.

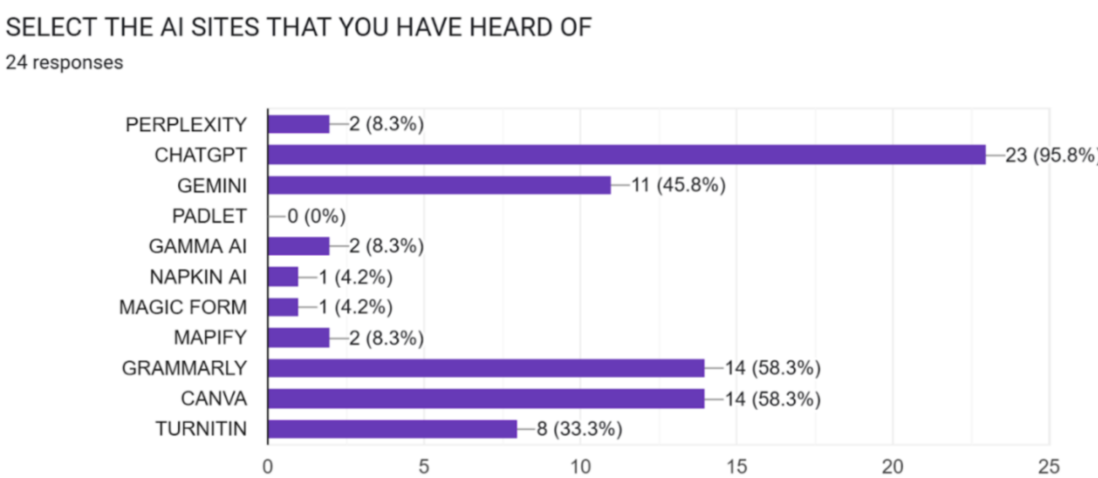

Chart 1.3

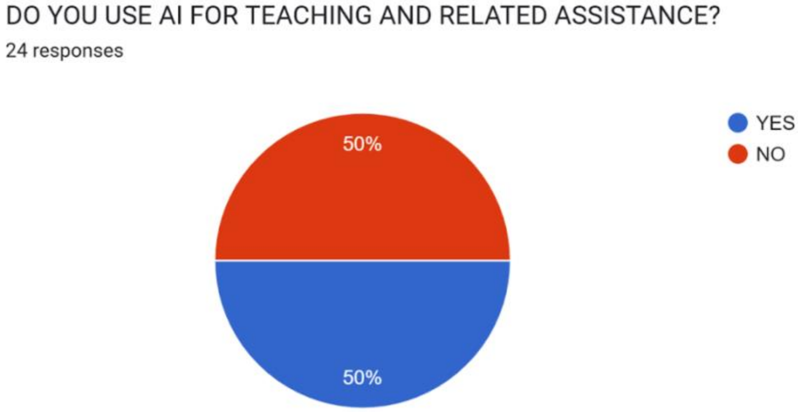

Chart 1.4

Nearly 37.5% of the educators are comfortable in using AI for education as shown in chart 1.5, and 41.7% gave a ‘maybe’ which can be interpreted as they have the efficiency to adapt when proper training is given to them. When we look into chart 1.6, we can see that most of the FDPs and PDPs haven’t taught or incorporated AI technology with education. Nearly 66.7% of the educators have voted that the FDPs and PDPs haven’t taught them on how to use AI in the evolving classroom environment or teaching. Since most of these educators are from government institutions it is a serious concern that the quality of education provided by the government needs improvement by structuring the FDPs and PDPs they organize to ensure quality education.

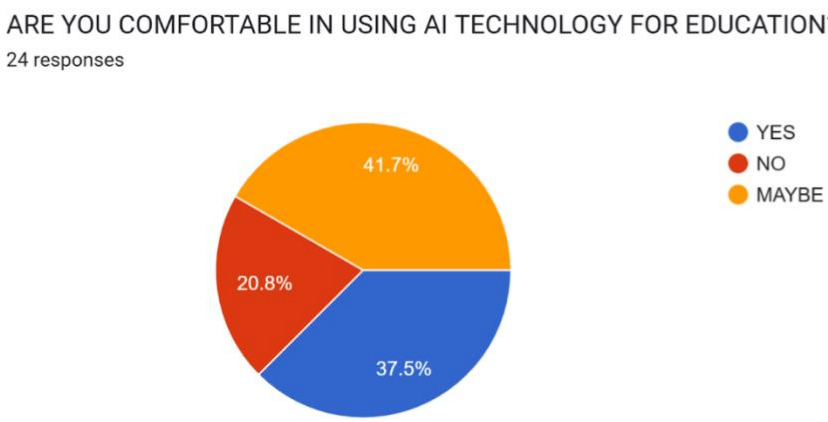

Chart 1.5

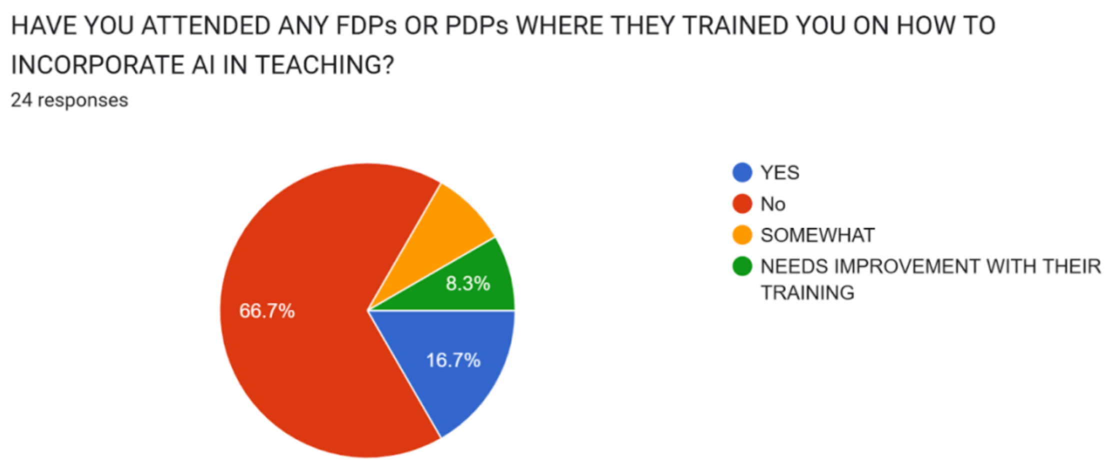

Chart 1.6

Most of these educators vote for hands-on training to adapt to the emerging technology. While teaching the educators, the FDPs and PDPs shouldn't focus only on giving a formal instruction. They should also incorporate Wenger's Communities of Practice while designing these programs for teachers. They should focus more on hands-on training, discussion, shared knowledge, giving their inputs and techniques to adapt to the new technology in the classroom environment. Since FDPs and PDPs already help to form a teacher community, we should focus more on the other aspects of Wenger's communities of practice to ensure effective learning among the teachers. These FDPs and PDPs shouldn't be designed as a one day workshop; instead the duration of these programs should last for atleast one week. This may help the educators to engage with each other, share their knowledge, opinion, solution and practice. This method gives them more time to practice and master how to use AI in a classroom environment. Once these programs get over, an online community or group can be created for a life-long learning as suggested in Wenger's community of practice.

- This ensures continuous learning among the educators to face the evolving classroom environment, and education.
- This will equip the educators and prepare them for AI infused teaching and learning.
- This will help them to explore the role of Wenger's CoP in supporting the effective implementation of professional development strategies.

LIMITATIONS

- This research paper and study is limited to Indian educators mainly to the cities of Tamil Nadu. So this study does not capture the perceptions of people from international platforms, and national platforms due to its smaller sample size.
- This study is limited to quantitative data collection method.
- This study is limited to general understanding, and usage of AI tools in teaching. It did not assess specific AI platforms, and training modules.
- This is limited to designing a professional development program for educators to integrate AI in their teaching, and related assistance.

VI. FINDINGS

This research paper explores the effectiveness of professional development programs like FDPs and PDPs in preparing the educators to navigate, and integrate AI into their teaching practice, and related assistance. The research aimed to analyze the current status of professional development programs in technological advancements, and evolving classroom environments, focusing on Indian educators, primarily from Tamilnadu. The data collected through a structured Google form survey revealed that the majority of the educators are willing to adapt AI enhanced teaching tools, but there was a significant gap in the training provided by the existing professional development programs. About 66.7% of respondents reported that the current FDPs and PDPs do not include adequate AI training, and 50% already use AI for their teaching without any formal training and support, this indicates a high demand for structured, hands-on, and contextually relevant professional development programs.

1. To what extent do the current professional development programs align with the technological and pedagogical need of teachers in an AI driven educational environment?

   Based on the survey conducted with 24 educators from various cities in Tamilnadu, the findings suggest that the current professional development programs do not align with the technological and pedagogical need of teachers in an AI driven educational environment. A significant 66.7% of educators reported that existing programs did not provide them with an insight or training to AI tools and strategies for integrating them into their teaching practice. This disconnection indicates that, while the educational technology is evolving, the professional programs remain outdated in most of the places and it remains insufficient in preparing the educators for the evolution.

2. What are all the challenges teachers face while adapting to AI infused learning environments, and how can professional development programs address these issues?

   Educators face several challenges while adapting to AI infused teaching as collected from the survey,
   - They are not exposed to AI tools and platforms.
   - They lack proper hands-on training to use AI in teaching.
   - Some of the educators are uncertain and hesitant to use AI in their teaching, and assess student's work.

   Professional development programs can address these issues by
   - Offering structured, hands-on training that goes beyond lectures and includes practical sessions.
   - Ensuring training is contextualized and relevant.
   - Creating a collaborative learning environment where teachers can share their experience and best practices.

3. What are teachers' perceptions about the existing professional development programs in helping them deal with the AI generated students output? From the data collected from the survey, teachers expressed a strong need for support in dealing with the student work created or assisted by AI. Many respondents were aware of the tools like ChatGPT, Gemini, and Grammarly being used by the students, but felt ill- equipped to use AI tools to check the authenticity and originality of their works. Only a small group of people are comfortable in using AI tools from the collected data and nearly half were unsure and some lack confidence in using AI tools. This survey implies a call for proper training and education for the educators in using AI for evaluating, teaching and related assistance.

4. What strategies can professional development programs implement to ensure teachers remain agile, and competent in technology infused classrooms over time?

To ensure ongoing adaptability and continuous learning, professional development programs should

- Incorporate Wenger's Communities of Practice model, by promoting peer-led learning and collaboration.
- It should be long term and continuous for effective learning, it shouldn't be like a one day workshop.
- It should establish online or hybrid communities for teachers to stay connected, update skills and share resources.
- It should include modules on digital ethics, academic integrity, and AI literacy.
- It should focus on hands-on training, experiential learning using real classroom scenarios.
- It should allow space for reflection and feedback, enabling teachers to evolve and adapt based on actual teaching experience.

5. How can Wenger's communities of practice be integrated while designing more effective professional development programs for teachers? This research paper strongly supports the integration of Wenger's Communities of Practice in designing effective Professional Programs. It can be done by,

- Domain: Establish a shared focus, so participants are united by a common purpose, In this case the focus should be on AI in education.
- Community: Build a learning community where educators can engage in regular interaction, discussion, peer support, and collaboration.
- Practice: Encourage teachers to co-create resources, share classroom experience and share practical strategies where they can apply directly.

VII. CONCLUSION

This research holds significance on many levels, both practical and theoretical especially at a time when education is undergoing rapid transformation due to technological advancements like AI. One of the most important implications of this paper is that the current status of professional development programs is insufficient. Through this research and data collection, it is evident that many educators are willing to adapt to the evolving technology in education by using AI tools in their teaching but they are not being provided with proper training and support to do so. This highlights a critical disconnect between what a teacher needs and what the current professional development programs are offering.

By applying Wenger's Communities of Practice as a theoretical framework, this study emphasizes on the value of peer-based, collaborative learning in teacher training. It suggests that professional development programs need to move beyond traditional lecture based models and instead, it should move towards creating ongoing interactive communities where teachers can learn from real world experience, exchange knowledge, and grow together. This shift and coverage has the potential to create more resilient, confident and technically equipped educators for the evolving classroom environment. The findings of this study also have implications on educational policy and institutional planning particularly in government run colleges of Tamilnadu, where most of the teachers from the survey participated. It is clear that investment in long term and meaningful professional development programs with an emphasis on AI literacy and hands-on training is not just beneficial but are immediately in need for effective learning and teaching. This research paper contributes to the field of teacher education through intentional design for professional development programs which was built upon a theoretical foundation like Wenger's Communities of Practice. This will lead to effective and lasting change in teaching practice for the evolving educational environment in technology.

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Implementation of Artificial Intelligence in Business Process Automation

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ABSTRACT

Business Process Automation (BPA) is a revolution of artificial intelligence (AI), that helps to improve efficiency and productivity of a business products. AI helps BPA to combines robotic process automation, natural language processing, and machine learning to increase the accuracy, and helps in decision making AI application is used in businesses to enter the data by doing data entry fraud detection, predictive analytics with the workflow optimization. Operational efficiency is further increased via AI-powered chat bots, virtual assistants, and intelligent process automation (IPA). It is seen that in every platform or sites artificial intelligence is used to predict the message or the content in the same way it helps in business process automation. In business BPA is used to examine the efficiency and increase it by using the various algorithm and strategies.

Keywords: *Efficiency, Productivity, Automation, Accuracy, Decision-making*

I. INTRODUCTION

All the businesses are using artificial intelligence (AI) to automate procedures, boost productivity, and improve decision-making in the changing technology. AI is essential to the advancement of business process automation (BPA), which helps to carry out repetitive operations. Machine learning, natural language processing, and robotic process automation (RPA) are all combined in AI-powered BPA increase accuracy, save costs, and expedite processes. AI-driven automation, from chatbots for customer service to intelligent data processing and predictive analytics, revolutionizes sectors by boosting output and facilitating more intelligent decision-making. The integration of artificial intelligence (AI) into business process automation is examined in this study, along with the main technologies involved, its advantages, and the difficulties that firms encounter when putting it into practice. Organizations may improve customer experiences, increase operational efficiency, and obtain a competitive edge in a world that is becoming more and more digital by utilizing AI-driven automation.

II. REVIEW OF LITERATURE

Researchers extensively examined that the incorporation of Artificial Intelligence (AI) into Business Process Automation (BPA). With an emphasis on important technologies, applications, advantages, and difficulties, this section examines the body of research on AI-driven BPA.

1. Business Process Automation with AI Technologies

Various research emphasize how AI technologies contribute to automation. Van dar Aalst (2018) asserts that by automating rule-based tasks and facilitating intelligent decision-making, robotic process automation (RPA) and artificial intelligence (AI) improve corporate productivity. Similarly, Bryn Jolfsson and McAfee (2017) talk about how ML works permit systems to evolve and adapt over time, resulting in increasingly complex automation solutions.

2. AI Applications for BPA

Two categories are used by Davenport & Ronanki (2018) to classify AI applications in BPA:
• Process Automation: AI-powered RPA lessens the need for human labor in repetitive processes like document processing and data entry.
• Cognitive Insights: Analytics driven by AI enhance risk assessment, fraud detection, and forecasting.

BASED ON PARAMETER	BPA	AI	SIMILARITY
Concentrate on accomplishing company goals	Aims to reduce costs and improve operational efficiency by automating	Manages intricate processes including thought, learning, and decision-making, going beyond straightforward automation.	The goals of both technologies are to improve organizational competitiveness, optimize operations, and boost company performance.
Automation as a fundamental idea	Follows preset guidelines to automate structured and routine tasks.	Extends automation to encompass intricate tasks that necessitate learning and flexible thinking.	They both emphasize automation as a means of promoting overall efficiency, but varying at degrees of complexity.
Reliance on Data	Uses data to carry out predefined actions and procedures.	AI uses data to learn, adapt, and make decisions on its own.	Both depend on data to function; AI uses it for ongoing learning, whereas BPA uses it for process execution.
Functionality	It can be integrated into existing systems to increase functionality without requiring a significant change.	Provides comparable integration opportunities while adjusting to current technological environments.	Both can be easily incorporated into existing systems to improve usefulness and efficiency.
Scalability for expanding businesses	By using automated procedures to manage growing workloads, it makes it simple to scale operations.	This equally scalable technology can handle increasing needs without significantly cutting back on human resources.	By enabling operational scalability, both technologies aid in the expansion of organizations.

Dedication to ongoing development	Able to continuously improve and optimize in response to user input	Designed from the ground up to become increasingly intelligent	Despite using distinct methods, AI and BPA are dedicated to various development activities.

3. Advantages of AI in BPA

Advantages of AI in automation are highlighted in a number of research. According to Willcocks (2020), AI-driven BPA improves scalability, boosts accuracy, and drastically lowers operating expenses. According to McKinsey (2019), companies that use AI automation get up to 40% increases in productivity and better decision-making.

Difficulties and Restrictions

AI-driven BPA has a number of drawbacks despite its benefits. Major obstacles include worker opposition, implementation complexity, and data privacy concerns Furthermore, research by Frank et al. (2021) emphasizes the necessity of ongoing control and monitoring to guarantee the ethical application of AI in automation.

Upcoming-Patterns

AI-driven Intelligent Process Automation (IPA), which combines AI, RPA, and advanced analytics, is predicted to further revolutionize enterprises, according to recent research. According to a Gartner (2023) report, 75% of businesses would use AI-powered BPA by 2025, increasing their flexibility and creativity.

How do Business Process Automation and Artificial Intelligence Work Together?
Despite having different uses and capacities, business process automation and artificial intelligence share a number of important characteristics. From common objectives in automation and business improvement to data reliance, integration, scalability, ongoing development, and decision-making assistance, these technologies converge at several points. However, it's important to understand their distinct features; for example, BPA's rule-based automation differs from AI's more sophisticated capabilities. But when combined, they can work in concert to maximize creativity and business potential.

III. AI Applications for Business Automation

Business process automation (BPA) and artificial intelligence (AI) can be used to achieve a number of important use cases in contemporary business. Among these use cases are:

Development and Research: In development and research artificial intelligence helps in supporting development of the automation by using various business processes.

Innovation and idea generation: AI algorithms are able to produce creative concepts for goods and services by examining customer behavior, market trends, and competitive environments.

R&D project management: Project management duties that guarantee effective team collaboration include scheduling, resource allocation, and progress monitoring.

Competitive analysis and market research: AI can automate the gathering and examination of competitor data, customer reviews, and market statistics, offering insightful information for strategic decision-making.

HR and recruitment: Because of the volume of paperwork and duties involved, HR and recruitment procedures are well suited for automation. Job advertisements, onboarding, compliance checks for new hires, and other HR duties like performance monitoring, timesheet tracking, and exit interviews can all be streamlined with automation. In addition to saving time, this enables HR staff to concentrate on important areas like health initiatives, culture development, and employee training. Here are a few examples of how AI may automate the HR department.

Resume screening: By automating resume screening and quickly comparing candidate profiles to job criteria, AI expedites the hiring process. This speeds up the first stage of hiring new employees, guaranteeing a more impartial and effective candidate selection process. **Predictive analytics:** AI analyzes past employee data to find trends and possible turnover indications. Organizations can proactively implement initiatives to improve work satisfaction, engagement, and overall employee retention by providing insights into the variables that contribute to turnover.

IV. CONCLUSION

According to the literature, artificial intelligence (AI) greatly improves business process automation through increased productivity, better decision-making, and improved customer relations. To fully utilize AI's promise in automation, companies must handle issues including data security, ethical considerations, and worker adaption. Best practices for integrating AI into business operations and AI governance should be the main topics of future study.

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A Review on Technology in Education for Differently Abled Students

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ABSTRACT

Technology involves utilizing scientific understanding, tools, and methods to develop systems, products, or processes that address problems and enhance human abilities. Technology's role in education includes enriching learning experiences using digital tools and resources, making information more accessible, and enhancing communication and collaboration among students and teachers. Technology in education significantly enhances accessibility and inclusivity for differently abled students. Tools like screen readers, speech-to-text software, adaptable keyboards, and customized learning applications can be utilized to overcome a variety of physical, sensory, and cognitive problems. By making it possible for students with disabilities to engage with educational materials, communicate more effectively, and participate actively in class activities, these assistive technologies promote personalized learning and guarantee equal learning opportunities for all. In this research paper, a review on technology in education for differently abled students is discussed. Assistive technology for children, different devices which can be used for differently abled students, categories and their services are also discussed in this research paper.

***Keywords**: Assistive Technology, Cognitive Disability, Differently Abled Students, Education, Technology*

I. INTRODUCTION

Technology has significantly impacted education, revolutionized teaching and learning processes [1]. It has made education more enjoyable and efficient, allowing for automation of tasks and improved knowledge dissemination [1]. Educational technology serves as a medium to enhance learning performance and increase student engagement through interactive tools and multimedia resources [2]. Various technology-based approaches have been studied, including computer-assisted learning, online courses, and digital personalized learning platforms [3]. Although there are many benefits to integrating technology into the classroom, it is important to see it as a tool to accomplish learning objectives rather than a goal in itself [4]. When the technology is integrated well, students may select the right resources for gathering, evaluating, and presenting information in a professional manner. However, further research is needed to fully understand the impact of technology on learning outcomes and to improve its integration in educational settings [3].

Types of Educational Technology

Instructional technology encompasses a wide range of tools and strategies for facilitating learning experiences in numerous different environments. They fall into four main groups:

expression, construction, communication, and inquiry. Technologies based on computers and mobile devices are some of the latest advancements in instructional technology, which have facilitated greater accessibility and comprehensibility of e-learning. Instructional technologies in medicine have increasingly been employed to foster novel pedagogical methods [20]. These technologies range from early instructional aides to more sophisticated uses including flipped classrooms, mobile devices, virtual and augmented reality, simulations, and collaborative learning [17]. More than 40 medical disciplines have used educational technology in medical education, and the majority of research have shown good evidence of their effects [20].

Advantages of Educational Technology for Institutions, Teachers and Students

With its many benefits for educational institutions, instructors, and students, educational technology has drastically changed the way that teaching and learning are conducted. It enhances student engagement, motivation, and learning [21] [22]. Distance learning and course delivery have been enhanced by the use of ICT resources including laptops, smartphones, and electronic whiteboards [22] [23]. Although appropriate training is necessary for its best usage, educational technology offers teachers new ways to efficiently convey knowledge [21] [12]. Institutions benefit from the digitization of classrooms and the ability to offer distance education [22] [23]. However, it's crucial to ensure that technology complements rather than replaces traditional teaching methods [22]. Overall, the adoption of educational technology has revolutionized the education sector, thereby creating more opportunities and improving the overall learning experience for all stakeholders involved in it [12] [23].

Educational technologies have become increasingly prevalent in modern learning environments, offering diverse tools to enhance the educational experience. These technologies include adaptive systems, cloud computing, and big data analytics, which enable personalized learning experiences and efficient resource management [13]. E-learning platforms have emerged as significant competitors to traditional education, utilizing 3D technologies, interactive tools, and mobile-based applications to facilitate knowledge transfer [13] [19]. In medical education, various technologies have been employed across more than 40 domains, with positive evidence supporting their benefits [20]. The integration of these technologies has led to substantial changes in educational environments, allowing for real-time monitoring of student performance, customization of learning strategies, and improved accessibility to educational resources [13]. As a result, educational institutions are increasingly adopting these technologies to modernize their teaching methods and enhance overall learning outcomes.

II. CHILDREN WITH DISABILITIES

The inability of a person with a disability to engage with an environment that does not support them is known as disability. When paired with other barriers, the physical, mental, intellectual, or sensory impairments that the majority of children in this age group have can prevent them from being fully and equally included in society [23]. Different types of disabilities found in children are discussed below.

1. Visual impairment: In this type of disability, an individual is due to poor vision, it is impossible to move independently.
2. Hearing impairment: In this kind of condition, the individual is either totally or partially deaf.
3. Language and Speech Disability: This category includes individuals with disabilities who have trouble expressing, receiving, and decoding language sounds.
4. Physical/Locomotor Disability: This type of disability prevents a person from walking, bathing, urinating, and doing other daily tasks.

5. Cognitive Disability: The phrase "cognitive disability" refers to a broad category of intellectual and cognitive impairments, including developmental disabilities, mental retardation, delayed development, and illnesses that cause cognitive impairment, such as neurodegenerative diseases or acquired brain injuries.

6. Children with learning disabilities: In this type of impairment, an individual faces several difficulties: problems in identifying themselves, decrypting and encrypting letters and syllables in words, problems in identifying numbers, and issues with calculation.

IV. ASSISTIVE TECHNOLOGY FOR CHILDREN

Assistive technology has emerged as a critical component in addressing the unique needs of students with disabilities, empowering them to overcome barriers and reach their full academic potential [22]. Over the last several years, the number of learning disability students has increased exponentially, and federal laws mandating "academic adjustments" for disabled students have prompted the creation of postsecondary learning disability support service programs to meet these growing demands [14] [15]. Within these support service programs, assistive technology has become a central focus, providing a range of tools and solutions that enable students with disabilities to access educational materials, participate actively in classroom activities, and demonstrate their knowledge and skills with greater ease and independence.

The key advantage of assistive technology is its ability to address the core challenges faced by students with learning disabilities [16]. Students with reading difficulties can benefit from text-to-speech software and digital reading tools, while speech recognition and word prediction programs can assist those with difficulties expressing themselves in writing [14] [16].

In addition to helping students with disabilities succeed academically, assistive technology can be extremely helpful in fostering the development of self-management and organizational skills, which are frequently necessary for success in postsecondary education [16].

A) **Assistive Inclusive Technology for Learning**

In the field of assistive technology, there are numerous myths. Students with disabilities are the only ones to use assistive technology. The misconception is that children with special needs are the only ones who can use assistive technology. The second myth is that assistive technology is too costly for low-resource nations to buy, despite the fact that it can help children from preschool through higher education. The third myth, assistive technology is an application of basic engineering for learning [12]. For example, most of the assistive technologies shown in Figure1 are not advanced. The use of assistive technologies for all age groups in shown in Figure 2.

Figure 1: Assistive Technologies [17]

Figure 2: Use of Assistive Technologies for all Age Groups [18]

B) **Assistive Technology Devices**

Assistive technology can improve participation and independence for children with special needs when it is appropriate to the user and the user's environment. It allows them to become independent and to have a voice in learning activity with peers. Students with special needs face a wide range of challenges when it comes to succeeding in an inclusive classroom. Selecting an appropriate assistive technology device plays a significant role in supporting their learning [20].

Assistive technology devices come in various categories such as visual impairment, physical disabilities and hearing impairment.

• Visual Impairment: Some of the assistive technology devices such as Braille products, low vision products, DAISY players, optical character reader and Braille printer comes under the category of visual impairment.

➢ Braille Products: Braille Sense U2 and Smart Beetle o Braille Sense U2: The blind can utilize the Braille tablet for a variety of tasks, from word processing, reading e books, web browsing, social networking, voice notes, and emailing as shown in Figure 3.

Figure 3: Braille Sense U2 [19]

Smart Beetle: This palm-sized Braille display provides Braille input and output to all mobile devices, including computers, phones and tablets, thanks to a USB port as well as up to five Bluetooth devices. It allows simultaneous connection to one USB and up to 5 Bluetooth devices as shown in Figure 4.

Figure 4: Smart Beetle [19]

➢ Low Vision Products: E-bot Pro, GoVision and Lifestyle HD 22

E-bot Pro: An adaptable, portable electronic magnifier with text-to-speech and optical character recognition (OCR) to reduce eye strain that connects to a range of screens as shown in Figure 5.

Figure 5: E-bot Pro [19]

GoVision: It is a dedicated USB drive offers unprecedented direct viewing access to videos, images, and documents as shown in Figure 6.

Figure 6: GoVision [19]

➢ DAISY Players: Blaze ET, 3Star, ReadEasy Move, Juliet Pro60 Braille printer

Blaze ET: Providing access to electronic documents and media for the visually impaired people as shown in Figure 7.

Figure 7: Blaze ET [19]

ReadEasy Move: It helps in Improving the access to printed material for the blind and print disabled by analysing printed text and reading it aloud as shown in Figure 8.

Figure 8: ReadEasy Move [19]

Juliet Pro60 Braille Printer: It is a durable and light weight Braille embosser for the blind and visually impaired as shown in Figure 9.

Figure 9: Juliet Pro60 Braille Printer [19]

2. Physical Disabilities: Special keyboard and special mouse are some of the assistive technology devices under the category of physical disabilities.

Special Keyboard: For those who are blind or visually challenged, the Bluetooth keyboard makes using their iPhones and iPads faster and more precise.

Figure 10: Special Keyboard [19]

Special Mouse: An enlarged track ball designed for people with poor dexterity who find it difficult to use a conventional mouse as shown in Figure 11.

Figure 11: Special Mouse [19]

3.Hearing Impairment: Image phone and digital assistive aids are some of the assistive technology devices under the category of hearing impairment [21].

Image Phone: It is a wireless and wired video phone with a widescreen for people who are hard of hearing or deaf to help with sign language communication as shown in Figure 12.

Figure 12: Image Phone [19]

C) **Assistive Technology Services**

These are the services that help a child with a handicap choose, buy, or use assistive technology gadgets in a direct manner. They are mentioned in the list below.

- The assessment of the student's technological demands, which includes a functional assessment in the person's usual setting.
- Acquiring assistive technology gadgets for students with impairments by purchase, leasing, or other means. • Choosing, creating, fitting, modifying, applying, and caring for assistive technology equipment.
- Syncing assistive technology devices with services.

IV.CONCLUSION

Through the provision of accessible resources, adaptable tools, and individualized learning experiences, technology has closed gaps and created new chances for these students to learn and achieve. From tailored learning platforms that meet a range of needs to assistive equipment like screen readers and speech-to-text software, technology enables students with disabilities to interact with education on their own terms. As a result, they can participate as much as they can with their peers in the educational environment, which helps them become more integrated. Technology will continue to play a major role in helping students with disabilities so that every student may perform to the best of their abilities.

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Artificial Intelligence for Disease Detection in Potato Crops under Smart Farming

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ABSTRACT

The global population has surged since 2022, heightening the urgency of ensuring food security amidst escalating demands. Agriculture remains pivotal in addressing this challenge, yet it grapples with the persistent threat of plant diseases, which contribute significantly to worldwide crop losses. However, accurately identifying these diseases, particularly in their early stages, remains a significant hurdle. Automated plant disease identification and diagnosis systems are thus indispensable. To confront this challenge, this study focuses on creating specialized databases for potatoes global food security. These crops face threats from various bacterial and fungal diseases, accentuating the urgency for effective disease management. Additionally, the study delves into developing a dataset specific to potato cultivation, a staple crop vulnerable to diverse diseases. Leveraging deep learning models for image classification, the study demonstrates the effectiveness of a single model, achieving approximately 83% accuracy in identifying potato crop diseases. Trained exclusively on the potato dataset, shows promising performance, paving the way for enhanced disease management strategies in potato farming.

Keywords— *Image Processing, Plant Disease Classification, AI in Agriculture, Convolutional Neural Network*

I. INTRODUCTION

In many nations, one of the main reasons for crop loss is plant diseases. Experts visually evaluate cases using traditional illness analysis methods, resulting in a longer diagnosis process compared to automation techniques. Additionally, there may be a scarcity of experts in some regions. To address this issue, automatic image analysis-based plant disease detection is crucial. Such automation not only expedites the diagnosis process but also serves a crucial function in assessing the seriousness of the condition, forecasting yield, and suggesting suitable treatments. Potatoes are essential food grains with numerous health benefits. They serve as vital sources of food and energy globally and are cultivated in large quantities to sustain expanding populations in many nations. However, like other food grains, potatoes are susceptible to various diseases and pests. Illnesses affecting potatoes can significantly hinder crop growth and reduce production. Common diseases include late blight virus Y, among others.

Convolutional Neural Network (CNN) has emerged as a popular method for plant disease detection, leveraging image analysis techniques. The effectiveness of convolutional neural networks is strongly influenced by the richness and size of the dataset. dataset used for training. Properly labeled, high- quality datasets are essential for optimal performance. Deep learning based CNN models require extensive data for training, as insufficient data can lead to diminished performance. Therefore, ensuring a sufficient volume of high-quality data is critical for training effective CNN models in potato disease detection. The objective of the proposed system are: i) To Develop a CNN architecture capable of accurately classifying images of plants into healthy or diseased categories, with further classification of specific diseases where possible. ii) Curate a comprehensive dataset of plant images covering various crops and diseases. iii) Analyze the effectiveness of the CNN model in recognizing and classifying plant diseases compared to existing methods and benchmarks. This paper has been organized as follows: The research subject, problem, and objectives are explained in detail in the first section. Section 2 provides an overview of current methodologies. System architecture and strategies are described in Section 3. In section 4, implementation details are provided, and the paper concludes with a conclusion.

II. LITERATURE REVIEW

To understand what has already been implemented and updated techniques used various papers are studied and explained in brief in this section.

Abdulridha et al.[1] focus on identifying target spot and bacterial spot illnesses in tomatoes using hyperspectral imaging techniques conducted via UAV (Unmanned Aerial Vehicle) and benchtop methods. It investigates the effectiveness of UAV- based hyperspectral imaging for early disease detection. Convolutional neural networks (CNNs) are used by Afonso et al. researchers in their publication [2] to identify blackleg illness in potato plants. It offers a CNN-based method for reliably and automatically identifying the signs of blackleg disease in potato plants. Afzaal et al. discuss the detection of early blight, a potato disease, using artificial intelligence methods, specifically focusing on remote sensing techniques in paper [3]. It draws attention to the timely identification and management of early blight in potatoes crops through the application of AI algorithms and remote sensing data. Agarwal et al. investigate computer vision-based methods for fruit disease categorization and detection in paper [4], hoping to take advantage of clever advancements in computational sciences and communication. It proposes novel computer vision algorithms for accurate and rapid detection of fruit diseases, contributing to advancements in agricultural technology.

Ahmad Loti et al. [5] offer a comprehensive analysis of both deep learning and machine learning. techniques for detecting diseases and pests in chili plants. It demonstrates the efficacy of machine learning and deep learning techniques in pest and disease identification, offering insights into precision agriculture practices. In paper [6] Al-Amin et al. Forecasting potato diseases based on leaf images utilizing deep convolutional neural networks, with the goal of enhancing digital agricultural systems. This paper presents a deep learning methodology designed for identifying potato diseases from leaf pictures, enabling prompt detection and management of health issues.

Aminuddin et al. [7] introduces an improved deep learning model for recognizing chili diseases, particularly focusing on handling small datasets effectively. It presents an advanced deep learning architecture tailored enabling the precise and effective identification of chili illnesses, tackling issues with the scarcity of data. In their study [8], Arshaghi et al. provide insights into multimedia tools and applications while discussing the application of deep learning methods for identifying and classifying potato diseases. Focusing on multimedia-enabled disease detection systems, it examines the use of deep learning strategies for the automatic recognition and categorization of potato illnesses. Arya Rajeev [9], makes a comparison between CNN and AlexNet for detecting diseases in potato and mango leaves. This research enhances the understanding of deep learning models within agricultural contexts by examining the comparative performance of CNN and AlexNet architectures for disease identification in potato and mango leaves.

In their research, Attri et al. provide an in-depth examination of the role of machine learning in agriculture, focusing specifically on crop management [10]. The study delivers a detailed overview of the machine learning techniques employed in agriculture, highlighting their contributions to various aspects of crop management, including yield forecasting and disease identification. In the research conducted by Ayoub Shaikh et al. [11], the potential applications and advancements of artificial intelligence and machine learning in precision agriculture and smart farming are explored. The paper discusses how AI and machine learning are being integrated into precision agriculture and the potential for these technologies to revolutionize farming practices and increase productivity. Basavaiah Anthony [12] focuses on classifying tomato leaf diseases by utilizing various feature extraction methods, contributing to wireless personal communication technologies are discussed. It introduces an innovative method for categorizing diseases in tomato leaves through various feature extraction techniques, which has potential applications for wireless communication technologies in agricultural settings.

BR et al. discusses a deep learning model for detecting and classifying plant diseases, as presented at the IEEE Third International Conference on Inventive Research in Computing Applications in 2021. This work introduces a deep learning model tailored for the recognition and classification of plant diseases. demonstrating its use at a prominent computer conference. In a paper [14], G. Arun presents a nine-layer deep convolutional neural network for detecting plant leaf illnesses, including information on electrical and computational and electrical engineering for agricultural applications.

Research from the 2019 IEEE Global Conference on Technological Advancement is presented by Govardhan Veena in paper [15], which addresses the use of random forest algorithms for tomato plant disease diagnostics. It investigates the application of random forest algorithms for diagnosing tomato plant diseases, with findings presented at a prominent global technology conference. These papers explore themes including the integration of technology for real-time illness diagnosis in potatoes, transfer learning, and the fusion of various imaging modalities.

III.PROPOSED SYETEM

The proposed systems aim is to develop a robust, accurate, and user friendly plant disease detection system that addresses the unique challenges and requirements of agricultural stakeholders. The system has various phases as shown in Figure 1 and explained further in this section.

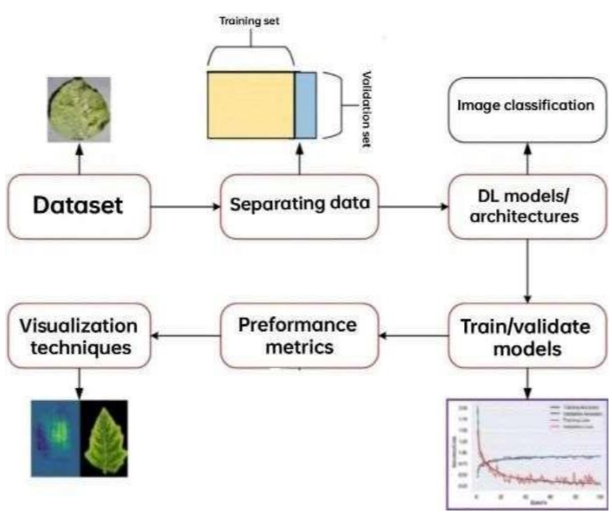

Figure 1: Proposed System

Data Acquisition and Preprocessing: A diverse and extensive dataset comprising plant images exhibiting various diseases has collected. Through rigorous preprocessing, including consistent labeling, standardized image resolution, and noise reduction is carried out to guarantee the dataset's dependability and quality.

CNN Model and Training: CNN architecture is used which is equipped with sophisticated methods like transfer learning and data augmentation. By setting up the model using weights that have already been trained from ImageNet, helps to expedite the training process and enhance generalization. Further refinement of the model is achieved through gradient descent optimization, minimizing classification errors specifically on the plant disease dataset.

Integration and Real-time Deployment: The proposed system has integrated the trained CNN model into mobile or online applications to facilitate the identification of diseases in real time. The system has an intuitive user interface designed for farmers and agronomists. Facilitating the seamless upload of plant photos and immediate access to disease identification results. Additionally, practical advice for disease management is provided to empower users in making informed decisions.

Data Separation: The dataset includes both training and validation sets. The model is trained using the training set, and the validation set is used to evaluate the model's performance and fine-tune its parameters.

Model Architecture: The model architecture refers to the composition and setup of the deep learning model used to classify images. Neural network Combinations of convolutional, pooling, and fully connected layers are often incorporated.

Image Classification: The technique of classifying photographs into predetermined groups or labels according to their content is known as image classification. During training, the deep learning model learns to identify features and patterns in the photos and classifies them accordingly.

Train/Validate: The model receives input photos from the training set during the training phase. It learns to associate input images with their respective labels by using optimization techniques like gradient descent. The effectiveness of the model is assessed with the validation set, and it modifies its parameters to improve both accuracy and generalization.

Feature Extraction: In the proposed system dataset have three types of potato leaves: a healthy leaf, one leaf affected by early blight and another impacted by late blight. Potato plants are vulnerable to two types of diseases: early blight and late blight. The leaves of the potato plant and stems get brown blotches from early blight. Blight that appears late causes large, water-soaked lesions on the leaves and stems, and can also cause the potatoes themselves to rot.

The proposed system automatically classifies potato plants as healthy, having early blight, or having late blight. This system could be used by farmers to identify and treat potato plants with blight early, which could help to improve crop yields.

IV. RESULTS AND DISCUSSION

The proposed system is evaluated by considering various images of potato crop. This dataset is used to train the model so that accuracy of the system can be improved. “Potato Late blight,” and” Potato Early blight” are possibly depicting potato plants affected by blight as shown in Figure 2. While the early and late blight images show leaf yellowing. Potato blight, a fungal disease, can devastate potato crops, causing brown spots in early blight and browning and withering of leaves in late blight, potentially affecting.

Figure 2: Sample of Dataset

Figure 3 displays the Graphical User Interface (GUI) of the system. It includes elements for user input, image display, classification results, navigation controls, and feedback mechanisms. The GUI is designed to be visually appealing, intuitive, and functional, facilitating user interaction with the software or application, such as a potato disease detection system.

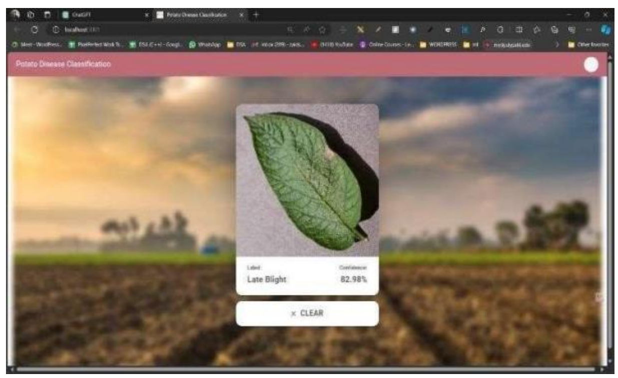

Fig. 3: GUI of Designed System

The trained model's effectiveness is evaluated through several performance metrics. These metrics include the confusion matrix, F1-score, recall, accuracy, and precision. These features help to highlight the model's predictive capabilities and identify potential areas for improvement. The accuracy chart generated for the specific dataset is shown in Figure 4.

Fig. 4: Training and Validation Accuracy

Figure 5 illustrates the loss achieved with the suggested system to meet the intended goal.

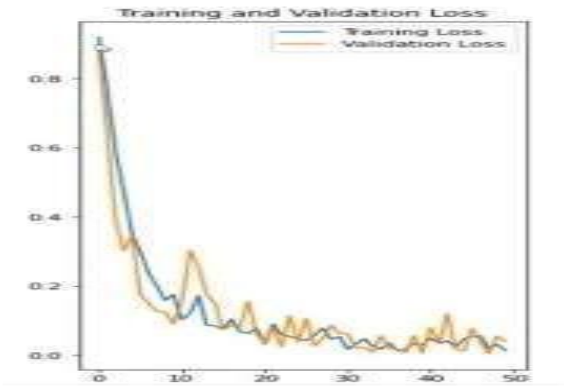

Fig. 5: Training and Validation Loss

V. CONCLUSION

The advancement of plant disease detection systems marks a notable stride in agricultural technology, providing farmers with real-time detection capabilities and enabling swift responses to diseases. Through overcoming accuracy and usability challenges, this solution boosts agricultural productivity and promotes sustainability, thereby aiding global food security efforts. The proposed system showcases technology's transformative potential in fostering resilient and sustainable farming methods, laying the groundwork for a more fruitful agricultural landscape.

The proposed system has successfully reached a significant milestone by achieving an accuracy of 84% in its diagnostics, surpassing initial performance expectations. This level of precision not only demonstrates the system's reliability in identifying specific conditions but also enhances confidence in its practical applications. The 84% accuracy rate is a testament to the effectiveness of the technological approach, validating the model's capabilities and laying the groundwork for additional improvements and practical implementation. This achievement underscores the potential of the project to contribute meaningfully to the field, ensuring more accurate and timely diagnostics in practical settings.

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Bridging the Gap between Theory and Practice in Rural Education through Digital Twin Technology

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ABSTRACT

Digital twin technology has opened up wide opportunities in various sectors such as smart cities, manufacturing, education and healthcare. Through the creation of immersive, interactive, and customized learning experiences, Digital twins create a virtual copy of real-world objects or environments, thus it has the potential to drastically alter experiential learning in the classroom with the help of immersive, creative and customized learning experiences. This paper aims to highlight the research on the theoretical reinforcements and real-world applications of digital twin technology in educational contexts. It focuses on creating a framework for digital twins, models of experiential learning, also examines possible case studies, points out advantages and challenges in implementation, and offers suggestions for further use. The study finds that digital twins have the ability to completely transform experiential learning by providing dynamic, real-time feedback, bridging the gap between theory and practice, and preparing students for issues they may face in the real world.

I.INTRODUCTION

Science, Technology, Engineering, and Mathematics, or STEM for short, this is very much essential for preparing students for the complex demands of the labor market in the twenty-first century. It develops essential skills that are crucial across many professions, including advanced problem-solving, technological proficiency, and analytical reasoning. However, rural schools often encounter major challenges in providing high-quality STEM education, primarily because of enduring problems like inadequate lab facilities, insufficient instructional resources, and limited access to state-of-the-art digital tools. These restrictions erode equitable access to opportunities for academic and professional development and deepen the learning divide between urban and rural pupils (Basumatary & Maity, 2024). Digital twin platforms and augmented reality (AR) are fortunately emerging as interesting and flexible alternatives. AR makes abstract subjects easier to understand by fusing digital elements with real-world situations to create immersive, hands-on experiences. Simultaneously, digital twins allow students to engage with and investigate dynamic models in real time without requiring conventional lab apparatus by simulating physical systems online (Vázquez et al., 2023).

Augmented reality (AR) has been shown to dramatically improve student engagement, comprehension, and retention in STEM fields. For example, in Ghana, interactive 3D images added to biology classes through AR-enabled smartphone apps increased student engagement and academic achievement (Asare et al., 2020). Similarly, a storytelling project in South Africa demonstrated AR's versatility across age groups and subjects by integrating cultural components into literacy training (Mpiti et al., 2023). The effectiveness of AR in promoting student-centered, immersive learning is demonstrated by early trials conducted in nations like Colombia and India, which show that rural students not only quickly adjust to AR tools but also exhibit a high level of enthusiasm for their use in the classroom (Sánchez-Obando & Duque, 2022; Basumatary & Maity, 2024).

The use of AR and VR in flipped classrooms in Malaysian rural schools resulted in significant gains in vocabulary acquisition and general learning outcomes, particularly for underachievers (Jalaluddin et al., 2024). According to study showing favourable opinions about AR's usefulness and usability in the classroom, teacher receptiveness is also increasing (Ripsam & Nerdel, 2024). The educational benefits of digital twins are equally intriguing. Despite having limited resources, students at a Mexican institution were able to provide realistic learning experiences by using these technologies to model engineering and aviation systems, allowing for hands-on involvement with complex mechanical components in virtual form (Vázquez et al., 2023). Teachers can promote more engaging, inclusive STEM teaching in rural classrooms by using AR and Digital Twin technology.

This paper aims to conceptualize how AR and Digital Twins can overcome rural-urban learning gaps in STEM education, with the ultimate goal of democratizing access to quality training and preparing all students, regardless of geography, for the digital future (Knysh et al., 2024).

II. RELATED WORK

In recent years, academics have shown a strong interest in the interface of immersive technologies and STEM education. Tools like Augmented Reality (AR) and Digital Twin systems have developed as strong enablers of interactive and student-centered learning, particularly in science, technology, engineering, and mathematics. In rural areas, where traditional resources like labs and contemporary teaching aids are limited, these technologies hold significant promise for resolving educational gaps.

2.1. Educational Potential of AR and Digital Twins

By turning abstract concepts into more approachable, visual experiences, augmented reality allows students to investigate and work with complex scientific phenomena in three dimensions. Similar to this, digital twin technologies improve functionality and authenticity in digital learning environments by enabling real-time simulations and monitoring of physical systems through virtual counterparts. Together, these resources support STEM education's dynamic feedback systems, hands-on learning, and higher-order thinking (Künz et al., 2022).

Global research repeatedly validates the educational usefulness of these developments. In a study examining AR's impact on student engagement, researchers found significant improvements in STEM-related academic performance and problem-solving skills (Muñoz et al., 2024). Similarly, Wang et al. (2024) discovered in their thorough meta-analysis that AR had a moderate but consistent favorable impact on science and math learning outcomes, especially for primary and lower secondary pupils.

2.22. Integration Challenges in Rural Contexts

Although the evidence for the effectiveness of these tools grows, adopting them in rural schools remains a big barrier. Infrastructure is one of the main challenges: widespread adoption is significantly hampered by poor internet connectivity, a shortage of mobile devices, and erratic electrical supplies. Only about 10% of AR educational resources are designed with rural settings in mind, according to studies, even in India, where AR pilot initiatives in rural primary schools have gotten good reviews.

Teacher preparedness is another urgent issue. Although AR tools are becoming more widely available, the author stresses that many teachers lack the knowledge or self-assurance to successfully incorporate them into their lessons, particularly in settings with limited resources. The results of a European teacher training study, which shown that focused professional development greatly increased teachers' readiness to integrate AR into STEM classroom, are consistent with this problem.

2.3. Digital Twin Applications in Education

Digital twin technology, which was first created for manufacturing and industrial environments, is currently becoming more popular in educational settings. Real-time simulation of cyber-physical systems is one important application that allows students to observe system activity, understand feedback dynamics, and conduct remote experiments (Castro et al., 2023). A similar strategy was used in a modular manufacturing station project, where students were given an almost real lab experience without the need for actual equipment by combining AR and Digital Twins to mimic industrial procedures (Caiza & Sanz, 2023). Another notable case study from the UK involved training technical staff using a Digital Twin of a railway station supplemented with augmented reality overlays. The study demonstrates how immersive visualization techniques may be successfully repurposed for complicated learning settings, despite its initial industrial function (Ackers, 2021).

2.4. Emerging Pedagogical Approaches

According to recent studies, using AR and Digital Twin technologies within constructivist, inquiry-driven, and multidisciplinary learning methods is beneficial. One effective application is employing augmented reality in STEM classes to assist students perceive chemical structures, which has been found to improve both retention and conceptual understanding (Midak et al., 2021). According to Valerio et al. (2024), integrating augmented reality (AR) with maker tools like 3D printers and modular kits like Infento encourages practical participation and innovative problem-solving. In rural classrooms, where traditional laboratory supplies are frequently scarce or non-existent, this immersive learning approach is especially well-suited (Valerio et al., 2024).

2.5. Gaps and Future Directions

A notable research gap is highlighted by the literature despite promising evidence: few extensive, long-term studies evaluate the real-world application of AR and Digital Twin technologies in underprivileged or rural schools. The majority of current research consists of short-term trials or pilot initiatives, frequently located in metropolitan or semi-urban areas. Furthermore, the focus is more often on technological skills than the infrastructure and sociocultural issues that impede equal adoption (Künz et al., 2022).
The lack of strong regulatory frameworks to support the broad integration of these tools into national education systems—especially in areas with disparate digital infrastructure—is another crucial problem. It is still challenging to scale these technologies without institutional support, which restricts their ability to bring about significant changes in education.

However, there is a lot of potential for integrating AR and Digital Twins into STEM education, especially in terms of increasing student engagement, enhancing conceptual comprehension, and developing practical skills. Even while the benefits of education are widely known, particularly in urban or industrial settings, there is a definite need for implementation plans and legislative measures that are specifically appropriate for rural learning environments. To properly utilize these technologies and aid in bridging the gap between urban and rural STEM education, it will be crucial to address fundamental obstacles including curriculum integration, teacher preparation, and infrastructure.

III. IMPLEMENTATION

A digital twin is a virtual model that reflects its physical counterpart. Digital twins offer a comprehensive view of physical entity's behaviour, condition and performance by using sensors, IoT devices, and real-time data analytics. For example, A digital twin of a classroom, replicates its layout, technology, and even human interactions, allowing teachers to test scenarios and tactics before putting them into practice in the actual world. The overview of digital twin is shown in Fig.1.

Digital twin comprises of various technologies such as

- Artificial Intelligence (AI) to predict the outcomes and to provide insights from data
- IoT Sensors to capture real time data
- Data Analytics that help to analyze and optimize the performance
- 3D Modelling that offers a realistic visualization of the virtual replica

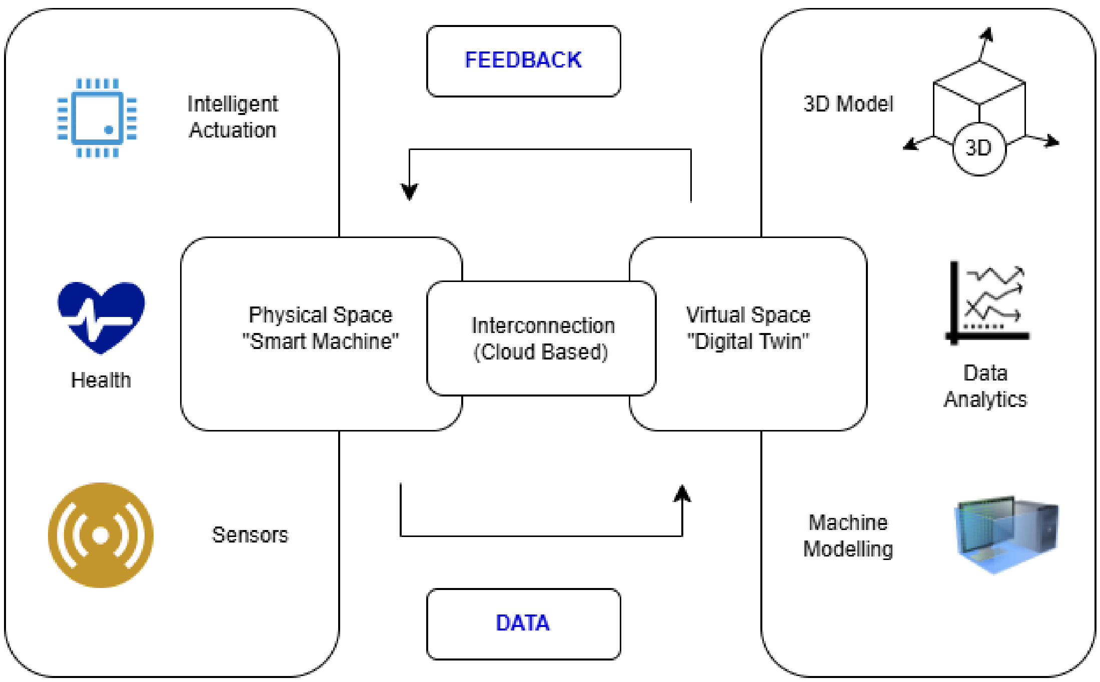

Fig.1. Overview of Digital Twin

Today, education has undergone a revolution since it is becoming more and more accessible to everyone because of the outreach of technology across various sectors. High-speed internet and reasonably priced internet gadgets have both fuelled the exponential growth of digital education, and we are currently on the cusp of yet another educational revolution. A classroom experience unlike any other is promised by the Digital Twins, the next wave of digital education.

Existing digital education models have effectively met the needs of many different sectors. You have the opportunity to start learning to code today by enrolling in Harvard's free online CS50 course immediately. Working individuals might choose to continue their education and careers by enrolling in an online MBA program. Now that the top teachers are offering classes online, students in rural places don't have to go far. Digital Twins are the next big thing that can happen with education, and the list is long enough to prove that digital education is the way of the future.

Digital Twin provides an AR (augmented reality) or VR (virtual reality) based learning experience and the learners are able to get better access to the content on whatever is being taught via running simulations. Fig.2. shows this model.

Applications of digital twin spread across multiple sectors of education and internet-based learning. It can give the experience of being physically present and thus have an improved outlook towards the session for any lecture classes, laboratory exercises and other applications also. It also aims at redefining the existing view of the classes, learning process for online as well as offline classes. This futuristic method involves simulation to visualization to synchronization.

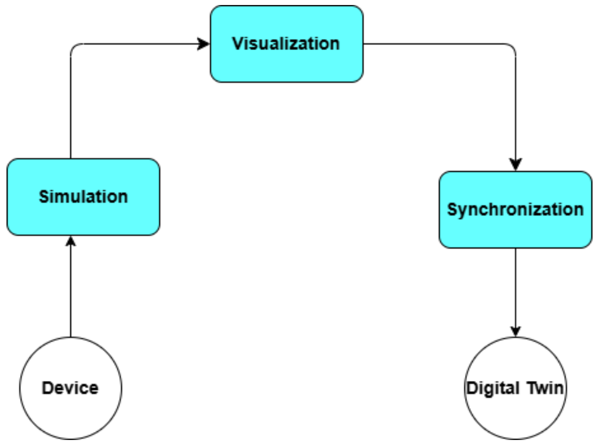

Fig.2. Technology behind Digital Twin

The better learning experiences are offered through simulating hardware and simulating processes. Many universities started to deploy digital twins to improve the teaching methods and also offers a more interactive way of learning to their remote students.

This conceptual paper uses a qualitative, analytical method to investigate how AR (augmented reality) and Digital Twin technologies may be strategically used to address the challenges in STEM (science, technology, engineering, and mathematics) education in rural schools. Since the methodology's main goal is to develop a conceptual understanding and future directions for implementation, it is primarily based on secondary data collection, framework synthesis and thematic analysis rather than empirical research.

First, databases like Scopus, Web of Science, ERIC, and Google Scholar were taken to do a comprehensive literature review. The review focused on peer-reviewed publications from the last ten years, including technology reports, conference proceedings, policy documents, and journals. Several combinations of search terms were used, such as "AR in education," "Digital Twin and learning," "virtual labs in rural schools," "immersive STEM education," and "technology in rural education." The chosen studies were divided into three main groups: (i) how well AR and Digital Twin tools may improve STEM teaching; (ii) case studies and pilot projects in underprivileged or rural areas; and (iii) educational policy frameworks pertaining to fair access to technology.

A comparative case analysis was also incorporated into the process, with an emphasis on a few international and Indian projects that used immersive technology in low-resource settings. These included UNESCO-supported augmented reality programs in Southeast Asia, digital twin-based simulations utilized in Finnish teacher education, and virtual lab projects supported by both public and private entities like the Atal Innovation Mission (AIM). The comparative method assisted in identifying best practices, enabling factors, and difficulties related to incorporating technology in STEM education.

Key obstacles and contextual factors, such as infrastructure readiness, teacher preparation, student learning results, engagement, and technological access, were also categorized using theme coding. A conceptual framework that links AR and Digital Twin treatments to particular educational requirements in rural environments was then created by synthesizing the emergent themes. The framework describes the expected results (e.g., enhanced conceptual comprehension, development of lab-based skills), mediating elements (e.g., learner motivation, curricular relevance), and input circumstances (e.g., device availability, instructor preparedness).

The National Education Policy (NEP) 2020, advancements on the DIKSHA digital platform, and the function of District Institutes of Education and Training (DIETs) are among the policy evaluations of Indian rural education programs that are consulted in order to assure contextual accuracy. Additionally, the current infrastructure and STEM learning conditions in rural schools were illustrated using figures from official sources like UDISE+ and ASER.

Furthermore, academic specialists in teacher preparation, rural school administration, and educational technology were consulted in order to improve the conceptual model. These stakeholders' input improved the model's applicability and validated its underlying assumptions.

Overall, this approach lays the groundwork for further empirical studies and pilot projects while providing an organized yet flexible framework for investigating the incorporation of AR and Digital Twin tools in rural STEM education.

The conceptual framework is further classified into three stages named research design, data collection and data analysis.

3.1 Conceptual Framework

Step 1: Research Design

A well prepared qualitative exploratory study design needs to be adopted that incorporates literature analysis, pilot case studies and expert interviews from various simulated educational environments.

Step 2: Data Collection

Data needs to be collected from various sources including academic journals, industry based white papers and semi structured interviews taken from education technologists and digital twin developers.

Step 3: Data Analysis

Conduct thematic analysis that helps to identify how digital twins can be perceived and applied in different educational settings and also their alignment with experiential learning outcomes.

IV. MODEL DESCRIPTION

The model starts with foundational inputs like teacher preparedness, syllabus integration, low-cost affordable technology and policy initiatives to support digital innovation in rural education. These inputs are given to the meditating mechanisms and this is called the operational heart of the system where in digital twin platforms combined with AR tools to deliver the STEM content in an interactive, locally customized manner. In the next step the blended pedagogical approach enhances the learning through culturally relevant and also makes the content linguistically accessible. They can be enhanced by adding interactive components such as quizzes, exploratory tasks and feedback modules that helps in reinforcing the concepts. The next step of model provides with several learning outcomes includes improved student attitudes, opportunity to bridge the gap in rural and urban education. Students also begin to develop digital competencies and problem-solving capabilities for higher education and employment. The final model of feedback loop ensures the sustainability and adaptivity of the model. Content updates, technology advancements, and pedagogical development are informed by evaluating student performance and teacher feedback, which makes the concept flexible and adaptable to changing rural learning environments.

The components of this conceptual model consist of input layer, mediating mechanism, output layer and feedback loop. This is illustrated in Fig.2. The details and examples for various component in each layer is described below.

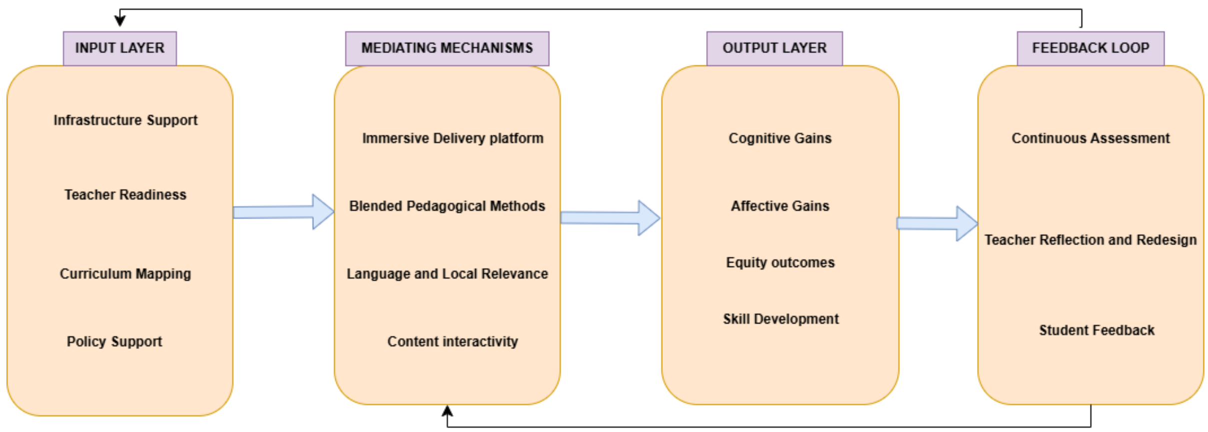

Fig.2 AR and Digital Twin-Enabled STEM Learning Framework for Rural Schools

4.1 Components of STEM Learning Framework:

1. Input Layer

a. Infrastructure Support – Local Servers, VR Headsets and Mobile devices
b. Teacher Readiness – Digital literacy and AR/VR pedagogical training
c. Curriculum Mapping – Alignment of digital twin and AR Content with syllabus of national and state.
d. Policy Support – Government or Institutional funding and Partnerships.

Mediating Mechanisms

. Immersive Delivery Platform – AR applications, Digital twin simulators and Virtual labs.
a. Blended Pedagogical Methods – A way to combine traditional setting with interactive simulations.
b. Language and Local Relevance – Customization to local language and Region-specific content
c. Content Interactivity – 3D Simulations, Quizzes, Real-Time system behavior and feedback loops.

Output Layer

. Cognitive Gains – Better understanding of STEM concepts
a. Affective Gains – Increased interest, Motivation and Confidence in STEM
b. Equity Outcomes – Reduced disparity of rural – urban in practical STEM exposure
c. Skill Development – Analytical thinking, Problem solving and Digital fluency

Feedback Loop

. Continuous Assessment – Real-time learning analytics and Adaptive content
a. Teacher Reflection and Redesign – Adjusting pedagogy based on reflection
b. Student Feedback – Insights into usability, interest and effectiveness in learning

V. FINDINGS

5.1. Enhanced Conceptual Understanding

The ability of digital twin (DT) and augmented reality (AR) technologies to improve conceptual comprehension through experiential and visual learning is a significant benefit in rural STEM education. The lack of laboratories and demonstration tools in rural locations often makes it difficult for traditional schools to teach abstract scientific concepts. By enabling students to visualize difficult concepts—like biological systems, force dynamics, and chemical structures—in interactive 3D environments, augmented reality (AR) helps bridge this gap. These immersive platforms facilitate deeper cognitive processing by allowing students to view and interact with digital representations of real-world phenomena. For instance, Muñoz et al. (2024) found that students who were exposed to AR-based STEM modules outperformed their peers who were taught using traditional methods in terms of comprehension and problem-solving abilities.

Similarly, Zhu et al. (2019) showed how combining AR and Digital Twins in manufacturing education enabled students to interact with ongoing operations and machine behaviour, successfully bridging the gap between theoretical instruction and real-world application.

5.2. Increased Student Engagement and motivation

Maintaining student interest in STEM subjects is a persistent challenge for rural educators, especially when topics seem abstract or irrelevant to daily life. AR and DT technologies have been shown to significantly boost engagement by introducing interactive, gamified, and contextually rich content. These tools create immersive environments that inspire curiosity and active participation. In a study conducted at a rural school in Malaysia, Wong et al. (2021) found that students exposed to AR-enhanced lessons exhibited heightened enthusiasm, stronger classroom attendance, and more collaborative learning behavior (Wong et al., 2021). Likewise, Lasica et al. (2020) noted that students in Cyprus and Greece showed increased interest and motivation in STEM fields when teachers implemented AR-supported inquiry-based learning strategies (Lasica et al., 2020). These outcomes shows how immersive technologies could transform passive instruction into dynamic and student-centered experiences.

5.3. Feasibility of Low-Cost Deployment

It's a common misconception that immersive technologies are too costly or unworkable for teaching in rural areas. However, by demonstrating affordable deployment alternatives with open-source platforms and popular mobile devices, a number of case studies challenge this presumption. For example, Caiza and Sanz (2022) created a functional Digital Twin system to model industrial processes using a Raspberry Pi and free cloud-based services. This model may be readily modified for STEM classes with no financial investment. Dani and Supangkat (2022) demonstrated in a different study that AR and DT tools may be effectively used with commonly accessible smartphones and tablets, doing away with the necessity for expensive proprietary equipment (Dani & Supangkat, 2022). These illustrations show that integrating immersive learning technologies into rural educational settings need not be hindered by financial constraints.

5.4. Reduced Urban-Rural Divide in Practical STEM Exposure

Urban and rural students' disparity in access to experiential STEM learning opportunities is a recurring problem in educational equity. Rural students are usually only able to get textbook-based training, whereas urban schools frequently benefit from fully furnished laboratories. By offering virtual labs and simulations that closely resemble real-world, practical experiences, augmented reality and digital twin technologies provide a means of bridging this gap. By using mobile augmented reality applications to access high-fidelity science experiments, Wong et al. (2021) showed that students in rural locations were able to close the experiential gap with their urban counterparts (Wong et al., 2021). Similarly, Prakash et al. (2024) created TwinVAR, which allowed students to interact remotely with Digital Twins in real time. It provided access to the same interactive models and simulations that are utilized in learning environments that are more sophisticated. These resources guarantee fair access to experiential STEM education for kids in remote areas.

5.5. Teacher Adaptability and Support as Key Enablers

The successful implementation of immersive technology is dependent on teacher preparedness and the availability of support services. Teachers in remote schools frequently face obstacles such a lack of training materials, apprehension about incorporating new technologies, and unfamiliarity with digital tools. According to Gargrish et al. (2021), in order to boost their confidence in the classroom, rural teachers indicated a great need for organized training courses and intuitive augmented reality platforms (Gargrish et al., 2021). In a similar vein, Ilona-Elefteryja et al. (2020) described a European program in which teacher preparation greatly improved the capacity to plan and present AR-supported STEM education, leading to better teaching methods and better student results. These observations highlight the fact that the effectiveness of technology ultimately rests on the empowerment of the teachers who use it.

5.6. Curriculum Alignment and Pedagogical Integration

The greatest impact of technological tools occurs when they are tightly matched with established pedagogical approaches and curriculum requirements. Meaningful educational outcomes are frequently difficult to achieve with standalone augmented reality or digital twin applications that are not directly linked to learning objectives. According to Lasica et al. (2020), AR modules that were customized to fit particular syllabus content—including native language options and regionally relevant scenarios—achieved superior learning results and higher acceptance rates among teachers and students. Many current AR and DT solutions prioritize technological novelty above pedagogical coherence, which restricts their scalability in traditional classroom settings, according to Künz et al. (2022), who conducted a comparable study. Educational information needs to be contextually grounded, instructionally sound, and interactive and engaging in order to be effective over the long run.

5.7. Connectivity and Infrastructure Gaps Persist

Although mobile-friendly AR and offline-compatible Digital Twin systems show promise, infrastructural inadequacies continue to pose significant obstacles in rural areas. Poor internet connectivity, fluctuating electricity, and restricted access to digital devices continue to affect many schools. Although low-cost AR solutions are technically possible, Dani and Supangkat (2022) emphasized that removing systemic infrastructural constraints is necessary for their wider deployment. According to Böhm et al. (2021), successful AR and DT applications, even in industrial settings, necessitate dependable backend systems and user-friendly interfaces, both of which need to be modified for educational purposes (Böhm et al., 2021). These results emphasize that in order to guarantee fair access; technical innovation must be combined with fundamental infrastructure upgrades.

VI. CHALLENGES

The first one concerns the information needed to create and update the DT on a regular basis. The volume of data that needs to be continuously collected, saved, and analyzed could impede the expansion of DTs if enough hardware and software infrastructure is not in place. It might not be a problem for small data sets (DTs) of objects and procedures, but for DTs of instructors and students, it is essential to collect as much data as possible so that the DT can be used for simulation and prediction.

Since it is nearly impossible to gather all of the information that could be known about a student in practice, particularly when they are completing coursework offline, any models or processes pertaining to the use of the learner DT must also account for the impact of "missing" data. One of the biggest obstacles to the acceptance and use of DT in higher education is teachers' digital

literacy, particularly for those with non-technical backgrounds.
The design of DTs combines a variety of disciplines, including as computer science, psychology, statistics, and mathematics.

A user can utilize DTs in educational settings more easily if they have at least a basic awareness of some of the key concepts, even though they are not required to be informed about all of these subjects. It is critical to comprehend the management approach that will be taken to ensure the sustainability of DT. The expense of ongoing development and processing is taken into consideration when maintaining DTs, in addition to allocating accountability for this maintenance. Depending on its size, protecting the DT's integrity and security necessitates taking into account a variety of extra aspects, especially when sensitive data may be involved.

Ensuring acceptable and ethical use of DTs in higher education is challenging, and is linked to data governance. The data that drives DT technology must be collected, stored, and used carefully to ensure that students are not put in danger. Learners must be given access to the data that drives the DT, and if at all feasible, DT managers and designers must discover out ways to give students authority over their data (Berisha et al., 2021).

VII. CONCLUSION:

Incorporating Digital Twin and Augmented Reality (AR) into STEM education in rural areas presents a significant chance to bridge the long-standing learning divide between students in rural and urban areas. Even in resource-constrained situations, these immersive tools make complicated STEM topics more approachable and captivating by enabling the establishment of virtual labs and real-time simulations (Zhu et al., 2019; Muñoz et al., 2024). The instructional value, technological promise, and equity-enhancing potential of these advances are highlighted in this paper's conceptual examination. Critical barriers in rural education, like low student engagement, inadequate lab infrastructure, and inadequate teacher preparation, are immediately addressed by AR and Digital Twin technologies by promoting interactive, hands-on learning (Wong et al., 2021; Gargrish et al., 2021).

These tools are useful ways to enhance learning outcomes and student motivation when they are given through mobile-compatible platforms and properly matched with curriculum goals (Lasica et al., 2020; Dani). However, key enablers like as content localization, teacher preparedness, policy support, and reliable infrastructure are necessary for their success (Ilona-Elefteryja et al., 2020; Böhm et al., 2021).
Even though issues like inadequate preparedness and weaknesses in digital infrastructure continue to exist, they are not insurmountable. To create scalable, context-specific models for implementation, educators, legislators, technologists, and local communities must work together in concert. Adopting AR and Digital Twin technologies in rural education ultimately reflects a dedication to guaranteeing that all students, regardless of geography, have equal access to explore, experiment, and succeed in STEM learning. It goes beyond simple innovation.

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AI-driven Insights for Learning Difficulties in Engineering Education: Predictive Approaches and Solutions

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ABSTRACT

Student Performance Analysis Tool for monitoring early engineering subjects in both students' and faculty members' roles. The tool keeps and uses test scores, offering education that meets the topics needed for the tests. The level of coursework expected is determined by the test result for each student. Depending on student achievement, teachers place them into the three categories Good, Average, or Needs Improvement. The system after that gives test-related review questions, video links from YouTube for more in-depth learning, and book concepts that are consistent with the course curriculum. It also states possible difficulties that can slow down a student's learning. With Python being its language, Pasta uses the tabulate library to show feedback in a well-structured way. There are six important subjects offered now: Engineering Mathematics-I, Engineering Physics, Engineering Chemistry, Basic Electrical Engineering, Programming in C, and Engineering Graphics. The subjects are split into separate modules to focus the student's answer. When analytics meet handpicked learning contents, the tool transforms the learning atmosphere into something useful for students.

Keywords: Student performance monitoring, Test-wise analysis, Subject-wise module tracking, Educational resource recommendations

I.INTRODUCTION

Evaluating student performance is an essential aspect of engineering education, serving not just to assign grades but also to identify areas where students may be struggling. Looking at how students perform in their assignments is very important, since this helps assign marks and also spot any struggles. In many cases, conventional tests mainly focus on numbers, which may not consider personal issues that could slow down a student's education. Therefore, we need other tools that look at different aspects than just the basic ones. Therefore, the Student Performance Analyzer has been developed to help assess first-year engineering students by using a personal approach. By going over the test scores and the syllabus topics tested in each exam, the tool helps to assess what the student understands about the subject. It is meant to go further than checking marks and provide feedback based on every student's journey in school.

The system identifies how well the performance is by classifying it as either Good, Average, or Improvement Needed. Moreover, the tool has a list of questions for review, links to videos on YouTube for better understanding, and it recommends textbooks relevant to the topics mentioned. One important thing about the analyzer is that it pays special attention to making sure no signs of potential learning problems are overlooked and that the environment supports each student in the right way. At the moment, the app helps you study six of the main subjects taught in the first year of engineering: Engineering Mathematics-I, Engineering Physics, Engineering Chemistry, Basic Electrical Engineering, Programming in C, and Engineering Graphics. Each topic is divided into parts so that the feedback is correct and helps improve the focus area in the test. Since the tool is written in Python and relies on the tabulate library, it brings users a clear and convenient way to use the app.

This study helps to improve learning results and the quality of academic life for engineering students through detailed evaluation and the adding of related resources and assistance.

II. LITERATURE REVIEW

[1] Gómez (2025) describes many of the aspects in which AI could improve engineering education. AI is able to facilitate learning when methods fit the strengths and weaknesses of the students, thus, the process becomes less daunting for students who struggle with different subject. It adjusts the learning experience to the student's performance and progress. For an instructor, AI can help complete time-consuming tasks such as grading and maintaining oversight. AI also facilitates maintaining clarity on how well the students are learning with very little effort. In general, this viewpoint is about how to enhance teaching and learning with AI in education. However, it does not dive into how AI enhances our ability to prevent learning issues or to predict students who may be struggling to learn. It does not talk about specifications of tools and solutions to deal with students who may struggle to learn, or predictably run into learning problems. In the end, the viewpoints of AI supporting education effectively are useful.

[2] Tlili et al. (2025) studied how AI helps improve learning in education. They combined results from many studies using a method called meta-analysis.
The research found that AI has a strong impact on student achievement (g = 1.10). Chatbots were found to be the most effective among all AI tools. Other systems like intelligent tutors and personalized learning tools also worked well. The study covered various subjects and levels, not just engineering. It focused on how AI improves learning but did not explore learning difficulties. No details were given about predictive tools or solutions for weak students. The findings show that AI is useful in general learning improvement. Overall, AI can support better results across different educational settings.

[3] Babu, M., Virgin, A., Edwin, M. R., Priya, G., & Ravichandran, K. (n.d.). Identifying Learning Difficulties at an Early Stage in Education with the Help of Artificial Intelligence Models and Predictive Analytics. INTERNATIONAL RESEARCH JOURNAL OF MULTIDISCIPLINARY SCOPE. The research looks into ways that predictive analytics can help detect difficulties and weaknesses in students' education. It shows that, if a problem is discovered late, a student may start to do poorly in school and face consequences to their well-being. Data-driven actions are recommended at the starting point to enhance achievements in education. The research investigates the use of intelligent tools in helping students learn personally and lightening the workload of teachers. It also pays attention to making decisions that are right, secure, and respect the privacy of everyone involved. Different types of data are put to use in machine learning to ensure students at risk are correctly found. Making updates to the models enables them to handle any changes in education. Imbalance caused by algorithmic bias and lack of equal tech resources is accepted as a major issue for fairness. For people to trust AI apps, they need to rely on ethical actions and open data. In the end, the study considers early detection to be essential for creating education systems that are better for all.

[4] Adeyeye, O. J., & Akanbi, I. (2024). The future of engineering education: a data analytics approach. This paper studies the ways in which machine learning and data analytics are impacting engineering professions by means of personalized learning. It relies on using recent data to help predict a student's achievements and design lessons to suit each student. Unique

learning behaviors are spotted by adaptive systems, helping to increase how interested students are and how well they do. Identifying at-risk students early is possible with such tools, so teachers can help as soon as possible. Using these technologies enables teachers to make better plans for their curriculum with the help of data. The paper draws attention to the ethical problems related to data and points out how key privacy, consent, and trust are required. It tries to overcome the problem that some regions do not have enough technology to take advantage of AI. It is very important to focus on equal access to benefit from new educational technologies. Key stakeholders working together is considered necessary to use AI responsibly and include everyone. All in all, the study seeks to create an education system that makes use of technology, is ethical, and better fits the expectations of work environments.

[5] Alam, A. (2023). Improving Learning Outcomes through Predictive Analytics: Enhancing Teaching and Learning with Educational Data Mining. International Conference Intelligent Computing and Control Systems. In this study, Educational Data Mining (EDM) is explored as a helpful method for improving how students learn using academic data. Using EDM helps expose useful trends that can inform how teachers instruct and choose learning theories that explain students' actions. Educators can find out about students' learning habits by examining their performance and the way they use tools in the classroom. By working with EDM, research gathers insights from lots of data for better guidance in education. It allows teachers to spot specific strengths and issues of each student, so they can modify the materials on the spot. The paper points out that EDM has the ability to determine academic performance, spot tough topics, and suggest helpful interventions. They improve teachers' responsiveness and encourage fast learning for students. Encouraging students' engagement is noticeable when their teaching is adapted to them individually. The research considers EDM as a way to bring positive changes to education. Overall, it proves that EDM helps shape choices that lead to greater success in schools.

[6] Harsha et al. (2024) Investigated how machine learning could enhance personalised learning. They developed predictive models using student data including previous marks and engagement, and used the models to help teachers understand each student's strengths and weaknesses. Regression methods were used which allowed students to be grouped more accurately for effective teaching. Predictive tools support early identification of students who may need additional support. The approach confirmed that predictive tools could provide focus in learning, reinforcing learning where the focus would be more effective.

[7] Vladova and Borchyk (2024) created a model to evaluate student performance, using several machine learning techniques. They used three methods: logistic regression, linear regression, and k-means clustering, for better accuracy. The model itself uses normalized scores, rankings, and comparisons of performance trends to improve accuracy. It predicts pass/fail outcomes with 90% accuracy and can estimate scores with 70% accuracy. Students are grouped based on similar behavior and/or learning patterns to provide better instructional support. This model is a helpful way to identify students who may not succeed early in the semester, and intervene in a timely way to improve student learning outcomes.

[8] Besbes (2016) created a learning environment enhancement plan (LEEP model) to assist with teaching and learning and educational improvement through data mining. It obtains data from classrooms, surveys and STEM exam scores to identify patterns of potential utility in learning. The framework incorporates aspects of cognitive science and education theory in order to create better ways to teach. Both numerical and descriptive data are examined to analyse how students are engaging with learning in classrooms. Ultimately, this allows the development of learner and educator profiles in order to create better teaching approaches. All in all, the LEEP initiative

champions students in a personalized learning experience and promotes educator improvements based on actual data from education and educational research.

[9] Boda and Svihla (2020) theorize about inequitable access to technology in STEM education. They articulate how technology can support and enlarge differences across students from different backgrounds. The chapter considers the importance of engaging with technological tools that are cognizant of students' cultural and social contexts. The chapter reflects on the importance of training teachers to be able to contextualize lessons that are more diversified and engage students more appropriately. Limited access to digital tools may limit certain students while providing more benefit to others with less need which provides additional complexity. The authors cast a vision for an equitable, tech-driven STEM education model that gives all students a fair chance to succeed.

[10] Ravikumar and Sasikala (2024) explore how predictive models can help improve engineering education. They link falling student numbers to job market concerns and stress the need to boost employability. The study uses student data to group learners based on academic background and personal skills. Teachers can use this grouping to adjust their teaching methods for different student needs. A linear regression model was used to predict CGPA, and clustering helped spot students needing extra help. While effective, the study doesn't discuss data bias or how well the findings apply to larger groups.

III. PROPOSED METHODOLOGY

The proposed methodology used for evaluating student performance across a variety of subjects and assessments, while offering suggestions to improve their performance using rule-based approach, includes the following actions:

- Data Structuring: It creates a dictionary that organizes specific data relevant to each subject which include: modules, important questions, main topics, textbook references, linked YouTube videos for help, and suggestions that vary according to each learning disability.

- Collecting User Input: The system prompts the user for the total number of students. For each student, it collects basic information (name and University Serial Number; USN). The user selects which assessment test the student took; Test 1, Test 2 or Test 3.

- Setting up Test Parameters: After selecting an assessment test, the program isolates the appropriate modules and identifies the maximum total marks:

- **Test 1:** Covers Module 1 with a maximum of 15 marks per subject.
- **Test 2:** Covers Modules 2 and 3 and has a maximum of 30 marks per subject.
- **Test 3:** Covers Modules 4 and 5 and has a maximum of 30 marks per subject.

- Record the Performance Data: The user enters the student scores for each subject on the selected test.

- Analyze the Performance: Each subject score for the student is analyzed into performance categories**:**

- **Needs Improvement:** Scores below a defined threshold.
- **Average:** Scores within a middle range.
- **Good:** Scores exceeding a higher threshold.

Generation of Personalized Feedback: For each subject, the program compiles: **Educational Records**

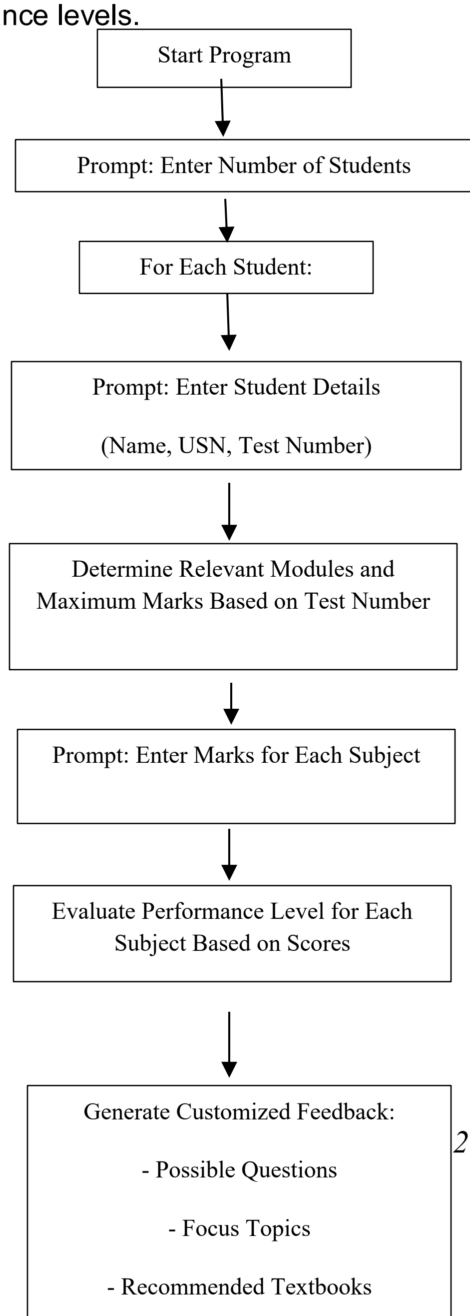
i) A selection of potential questions from the pertinent modules to guide targeted study.
ii) Primary topics that warrant attention based on the student's performance.
iii) Recommended textbooks for comprehensive understanding.
iv) Curated YouTube links for visual and auditory learning support.
v) Information on any learning disabilities relevant to the subject, providing insights into potential challenges and accommodations.

Compilation and Presentation of Reports:

i) The program organizes the collected data into a tabular format, delivering a detailed report for each student.
ii) This report encompasses the student's scores, performance level, suggested study materials, and additional resources.

Visual Representation of Performance:

A pie chart is generated to visually represent the student's overall performance in the test. The below Fig.1 illustrate the proportion of total marks obtained relative to the maximum possible, categorized by performance levels.



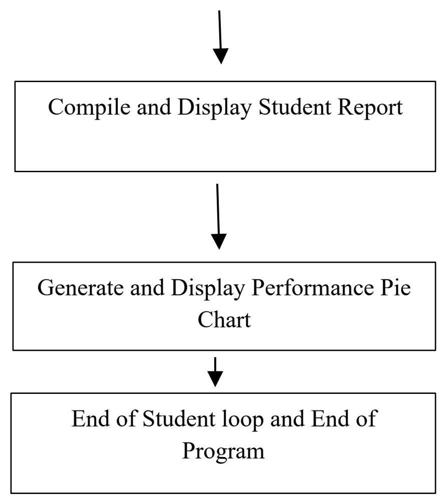


Fig 1: Flow Diagram of Proposed Methodology

Assessing student performance across various subjects and tests requires a structured approach to provide personalized improvement suggestions. Initially, it's essential to organize detailed information for each subject, including modules, potential questions, key topics, textbook references, supplementary YouTube links, and considerations for specific learning disabilities.

IV. RESULTS AND DISCUSSION

The process begins by collecting user input: determining the number of students and gathering each student's personal details, such as name and University Serial Number (USN). Additionally, identifying which test—Test 1, Test 2, or Test 3—the student has taken is crucial. Based on the selected test, the relevant modules and maximum possible marks are established:

Test 1: Covers Module 1 with a maximum of 15 marks per subject.

Test 2: Encompasses Modules 2 and 3, totaling a maximum of 30 marks per subject.

Test 3: Includes Modules 4 and 5, also with a combined maximum of 30 marks per subject.

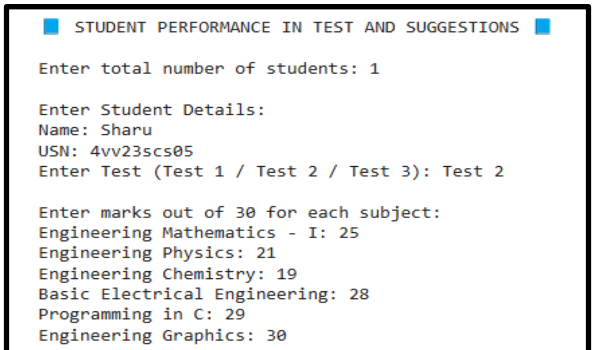
During performance data entry, the user provides the marks obtained by each student in their respective subjects and selected test. Based on these scores, the system assesses and classifies the performance into three distinct categories.: **Need Improvement**, **Average**, **Good**

Subsequently, customized feedback is generated for each subject, compiling:

- A list of potential questions from the relevant modules to guide focused study.

- Key topics that require attention based on the student's performance.
- Recommended textbooks for in-depth understanding.
- Curated YouTube links for visual and auditory learning support.
- Information on any pertinent learning disabilities, offering insights into potential challenges and accommodations.

The information is organized in a logical table layout, and provides a comprehensive report for each student. The report includes their marks, category performance levels, recommended learning materials, and other resources. In addition, each student has a pie chart that summarizes the marks received and total possible, broken down by category. This is done for each student individually so that they receive an assessment and the recommendations are directed toward them.



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STUDENT PERFORMANCE IN TEST AND SUGGESTIONS

Enter total number of students: 1

Enter Student Details:
Name: Sharu
USN: 4vv23scs05
Enter Test (Test 1 / Test 2 / Test 3): Test 2

Enter marks out of 30 for each subject:
Engineering Mathematics - I: 25
Engineering Physics: 21
Engineering Chemistry: 19
Basic Electrical Engineering: 28
Programming in C: 29
Engineering Graphics: 30
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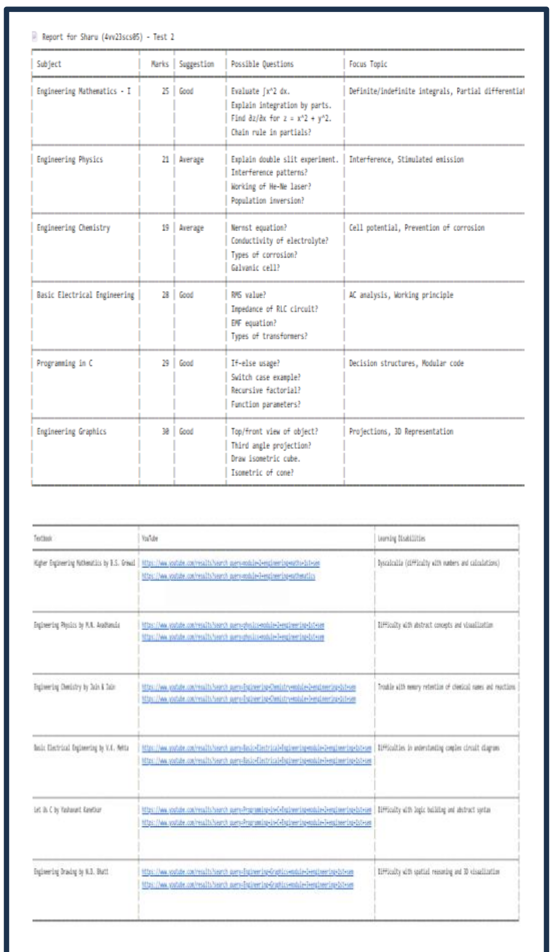
Fig 2: Student Input Interface for Generating Personalized



Report for Sharu (4vv23scs05) - Test 2

Subject	Marks	Suggestion	Possible Questions	Focus Topic
Engineering Mathematics - I	25	Good	Evaluate ∫x^2 dx. Explain integration by parts. Find ∂z/∂x for z = x^2 + y^2. Chain rule in partials?	Definite/indefinite integrals, Partial differentiat
Engineering Physics	21	Average	Explain double slit experiment. Interference patterns? Working of He-Ne laser? Population inversion?	Interference, Stimulated emission
Engineering Chemistry	19	Average	Nernst equation? Conductivity of electrolyte? Types of corrosion? Galvanic cell?	Cell potential, Prevention of corrosion
Basic Electrical Engineering	28	Good	RMS value? Impedance of RLC circuit? EMF equation? Types of transformers?	AC analysis, Working principle
Programming in C	29	Good	If-else usage? Switch case example? Recursive factorial? Function parameters?	Decision structures, Modular code
Engineering Graphics	30	Good	Top/front view of object? Third angle projection? Draw isometric cube. Isometric of cone?	Projections, 3D Representation

Textbook	YouTube	Learning Disabilities
Higher Engineering Mathematics by B.S. Grewal	https://www.youtube.com/results?search_query=module+2+engineering+maths+1st+sem https://www.youtube.com/results?search_query=module+3+engineering+mathematics	Dyscalculia (difficulty with numbers and calculations)
Engineering Physics by M.N. Avadhanulu	https://www.youtube.com/results?search_query=physics+module+2+engineering+1st+sem https://www.youtube.com/results?search_query=physics+module+3+engineering+1st+sem	Difficulty with abstract concepts and visualization
Engineering Chemistry by Jain & Jain	https://www.youtube.com/results?search_query=Engineering+Chemistry+module+2+engineering+1st+sem https://www.youtube.com/results?search_query=Engineering+Chemistry+module+3+engineering+1st+sem	Trouble with memory retention of chemical names and reactions
Basic Electrical Engineering by V.K. Mehta	https://www.youtube.com/results?search_query=Basic+Electrical+Engineering+module+2+engineering+1st+sem https://www.youtube.com/results?search_query=Basic+Electrical+Engineering+module+3+engineering+1st+sem	Difficulties in understanding complex circuit diagrams
Let Us C by Yashavant Kanetkar	https://www.youtube.com/results?search_query=Programming+in+C+Engineering+module+2+engineering+1st+sem https://www.youtube.com/results?search_query=Programming+in+C+Engineering+module+3+engineering+1st+sem	Difficulty with logic building and abstract syntax
Engineering Drawing by N.D. Bhatt	https://www.youtube.com/results?search_query=Engineering+Graphics+module+2+engineering+1st+sem https://www.youtube.com/results?search_query=Engineering+Graphics+module+3+engineering+1st+sem	Difficulty with spatial reasoning and 3D visualization

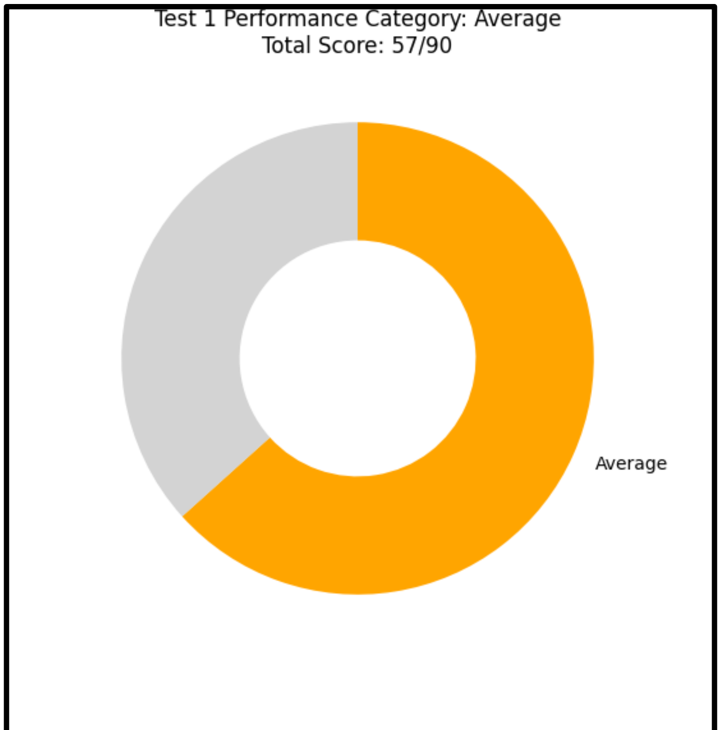
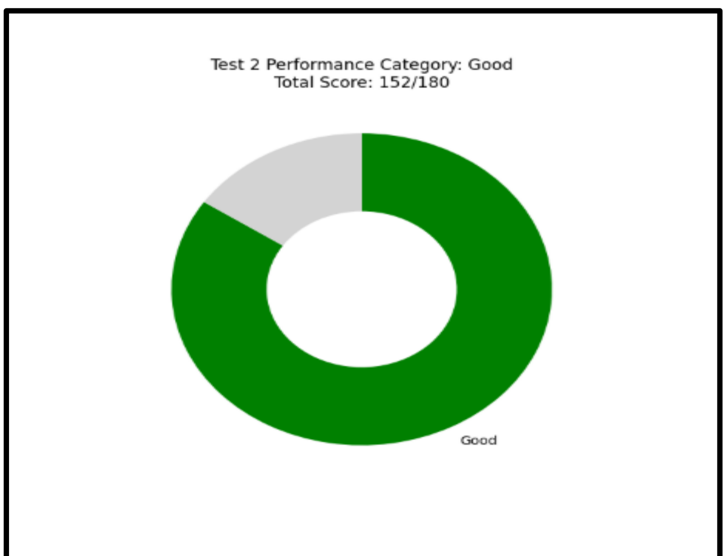


Fig 4: Donut Chart Representing Test 1 Performance Category and Total

Fig 5: Donut Chart Representing Test 2 Performance Category and Total Score



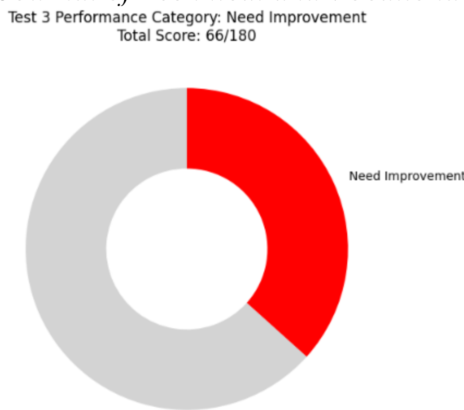


Fig 6: Donut Chart Representing Test 3 Performance Category and Total Score

The Fig 2 to Fig 6 show a system that collects student test data and provides feedback on each subject area. The system originally provides detailed 'reports' containing marks, learning resources, and subject-specific focus areas. It also makes 'donut' charts to help visually represent level of overall performance in terms of Test 1, Test 2, and Test 3, and these visualizations help quickly identify whether the student's performance is Good, Average or Needs Improvement. Overall, the system enables personalized learning by linking scores to specific resources and suggestions.

V. CONCLUSION

The assessment of student performance across subjects and tests is a structured process designed to recommend individual student pathways toward learning growth. Academic or content-based information is the first step in organizing subject content (which content is sequenced into modules, along with guides for open learning five of the top ten questions being asked, highlighted content within modules, recommended textbooks, free Youtube video explanations, gained insight into recommended supports for any learning challenges). The program starts with the request for the number of students were to be analyzed entered and recorded essential information for students, name and University Serial Number (USN), and indication of which one of the three test modules Test 1, Test 2, or Test 3 was attempted. Each test had specific modules and specific marks distributions attached to them:

- Test 1 assesses Module 1, with a maximum of 15 marks per subject.
- Test 2 covers Modules 2 and 3, with a combined total of 30 marks per subject.
- Test 3 focuses on Modules 4 and 5, also carrying a maximum of 30 marks per subject.

Upon selecting the test, the user enters the scores for each subject. Then, those scores are examined and placed into one of 3 categories: Need Improvement, Average, Good

The evaluation standards can vary depending on the test format so that it reflects the correct score value ranges. Based on those classifications, the system will provide individualized feedback per subject that will include:

- A bank of recommended questions based on the test modules the students received
- Topics to note for further practice

- Relevant textbooks for further study
- Curated videos for additional help
- Notes on relevant learning disabilities and supports

All the feedback will be presented in a clear table format and will provide a complete overview of each student that is individualized. The process will also produce a pie chart for each student that demonstrates their score and the distribution of scores and level of performance. This process will repeat this process for all the students to ensure that the reports are personalized and detailed.

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