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A Framework for ICT-Enhanced Competency-Based Curriculum in Indian Primary Schools: The Role of AI, Deep Learning, and Fuzzy Logic

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Abstract: The competency-based curriculum (CBC) used in elementary schools in India includes an extensive computational foundation for incorporating information and communication technology (ICT). To improve overall learning results, tailor instruction to the requirements of each student, and enrich the educational experience, the suggested framework makes use of the strengths of Artificial Intelligence (AI), Deep Learning (DL), and Fuzzy Logic (FL). The development of digital literacy and problem-solving abilities necessary for 21st-century learners depends on the incorporation of ICT into CBC. Our strategy involves creating AI-powered personalized learning environments that adjust to each student's particular learning preferences and speed. To provide individualized instructional materials and interventions, deep learning algorithms are used to evaluate student performance data and forecast learning trajectories. Fuzzy logic is utilized to address the intrinsic uncertainties present in educational evaluations and to enable more complex and adaptable assessment standards. Since Indian primary schools have a variety of instructional situations, the framework is made to be both flexible and scalable. Our framework's effectiveness in boosting student engagement, encouraging critical thinking, and raising academic achievement is demonstrated via case studies and experimental deployments. The findings demonstrate how artificial intelligence (AI), deep learning, and fuzzy logic have the potential to completely transform elementary education by increasing its effectiveness, inclusivity, and efficiency. As a conclusion, this article highlights how important sophisticated computational technologies are to the modernization of elementary education and argues for a wider use of these technologies in the Indian educational system. If educators, legislators, and technologists are looking to introduce a competency-based curriculum improved by ICT in elementary schools, our results will be of great use to them.

Keywords: *ICT Integration, Competency-Based Curriculum, Primary Education, Artificial Intelligence, Deep Learning, Fuzzy Logic, Personalized Learning, Educational Technology, Indian Schools, Adaptive Learning, Digital Literacy, Student Performance, Educational Framework, Smart Education.*

1. Introduction

Information and communication technology (ICT) integration is now essential in creating a 21st-century learning environment because of how quickly education is changing. The development of information and skills that students should possess by the conclusion of their educational journey is emphasised by competency-based curriculum, or CBC. This method is especially important in the setting of primary education, when fundamental skills in problem-solving, critical thinking, reading, and numeracy are developed.

The implementation of an efficient and equitable primary education system presents particular problems for India, given its heterogeneous educational environment. A one-size-fits-all approach that can impede the development of important competences is brought about by the traditional methods of teaching and evaluation, which frequently fail to meet the unique requirements of learners. These problems may be resolved in part by integrating ICT into CBC, which makes it possible for more successful educational approaches and customised learning experiences.

Technological innovations that have the potential to revolutionise elementary education include Artificial Intelligence (AI), Deep Learning (DL), and Fuzzy Logic (FL). Artificial Intelligence possesses the capability to generate learning environments that are adaptable to the distinct learning styles and speeds of individual pupils. In order to forecast student performance and pinpoint areas that require assistance, deep learning algorithms can evaluate enormous volumes of educational data. The flexible framework offered by fuzzy logic allows for a more nuanced assessment of student skills due to its capacity to manage imprecision and ambiguity.

This study enhances the ICT integration in CBC for Indian primary schools by presenting a complete computational framework that leverages the capabilities of AI, DL, and FL. With the use of this framework, an educational model that is both scalable and flexible would be able to meet the varied

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demands of Indian students from a range of socioeconomic backgrounds and geographical locations.

We start by going at how ICT integration is currently going in Indian elementary school and the difficulties in putting CBC into practice. We next go into depth about the suggested computational architecture, emphasising how these problems may be solved by utilising AI, DL, and FL. We illustrate the usefulness and advantages of our framework in authentic learning environments with case studies and experimental projects.

A major step towards modernising elementary education in India has been taken with the implementation of this framework. Through the use of cutting-edge computational technologies, we hope to build an educational system that is more effective, efficient, and inclusive while also preparing students for the needs of the future. The ultimate goal of this research is to enhance the quality of teaching and learning in Indian public primary schools by offering a systematic framework for integrating ICT for academic achievement across a range of learning environments, as illustrated in Fig. 1.

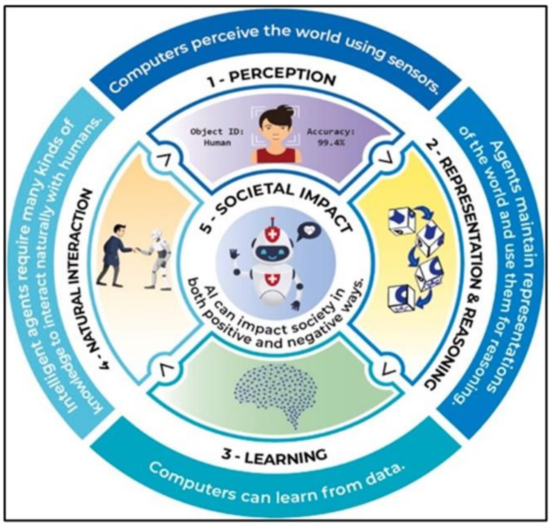

Fig. 1 To show the Societal impact of AI in Society.

2. Related Work

The integration of Information and Communication Technology (ICT) in education, coupled with advanced computational techniques such as Artificial Intelligence (AI), Deep Learning (DL), and Fuzzy Logic (FL), has garnered significant research attention. This section reviews relevant literature that informs our proposed computational framework for integrating ICT into the competency-based curriculum (CBC) for Indian primary schools.

ICT in Education

Baneres, D., et al [1] - Provided a comprehensive overview of global ICT policies in education, identifying key challenges and opportunities.

Khan, N.A., et al [2] - Emphasized the role of ICT in promoting educational equity and quality, especially in developing countries.

Kickbusch, I., et al [3] - Highlighted the benefits of ICT in education and its potential to enhance learning outcomes.

Kurniawan, T.A., et al [4] - Examined the impact of ICT initiatives in Indian primary education, noting its potential to bridge the digital divide.

Competency-Based Education

Magrini, C., et al [5] - Discussed the importance of personalized learning pathways in competency-based education (CBE).

Marouli, C., et al [6] - Advocated for flexible pacing and competency-based assessments in CBE.

Dabic-Miletic., et al [7] - Stressed the need for a competency-based curriculum to equip students with critical skills.

Artificial Intelligence in Education

Avelar, A. B. A, et al [8] - Reviewed various AI applications in education, including intelligent tutoring systems and predictive analytics.

Chankseliani, M., et al [9] - Demonstrated the effectiveness of AI in enhancing student learning experiences.

Purcell, W.M., et al [10] - Explored the role of AI in personalizing learning and providing real-time feedback.

Qushem, U.B., et al [11] - Discussed the impact of AI on higher education and its potential to transform learning.

Deep Learning in Education

Abdulloev, I., et al [12] - Investigated the use of deep learning for predicting student performance.

Kuleto, V., et al [13] - Explored the application of deep learning in adaptive learning systems.

Zhai, X., et al [14] - Provided a systematic review of AI and DL applications in education.

Adiguzel, T., et al [15] - Studied the use of DL for automatic grading and feedback systems.

Fuzzy Logic in Education

Alam, A., et al [16] - Introduced the concept of fuzzy logic, which has been applied in various domains including education.

Chen, X., et al [17] - Reviewed the use of fuzzy logic in educational assessment.

Jaiswal, A., et al [18] - Applied fuzzy logic to develop adaptive testing systems.

Kamruzzaman, M.M., et al [19] - Explored the application of fuzzy logic in managing educational data and decision-making processes.

Existing Frameworks

Al-Ansi, A.M., et al [20] - Proposed the TPACK framework, highlighting the intersection of technological, pedagogical, and content knowledge.

Jurayev, T.N., et al [21] - Developed the SAMR model, providing a roadmap for meaningful technology integration in education.

Pham, Q. D., et al [22] - Presented a conversational framework for the effective use of technology in teaching and learning.

Advanced Computational Techniques

Carayannis, E.G., et al [23] - Explored the potential and implications of AI in various domains, including education.

Mian, S.H., et al [24] - Provided foundational knowledge on deep learning techniques and their applications.

Montoya, M.S.R., et al [25] - Introduced fuzzy logic and its applications in decision-making and control systems.

Burdina, G.M., et al [26] - Discussed the principles and applications of fuzzy systems in control and decision-making processes.

Mićić, L., et al [27] has proposed a review of related work that underscores the significant advancements in ICT integration, AI, DL, and FL in education.

Gaol, F. L., et al [28] - Discussed various frameworks and approaches for integrating ICT in educational settings.

While substantial progress has been made, there remains a gap in comprehensive frameworks that combine these technologies to enhance competency-based curricula, particularly in the context of Indian primary education. Our proposed framework aims to fill this gap by offering a holistic approach that leverages the strengths of AI, DL, and FL to create a scalable and adaptable educational model.

3. Proposed Work

The present study suggests an all-encompassing computational framework for the incorporation of Information and Communication Technology (ICT) into the competency-based curriculum (CBC) of elementary schools in India. To provide a dynamic, individualised, and productive learning environment, the framework makes use of the capabilities of artificial intelligence (AI), deep learning (DL), and fuzzy logic (FL). Improving learning outcomes, attending to the unique requirements of each student, and preparing them for the challenges of the twenty-first century are the main objectives.

3.1 Overview of the Framework

Personalised learning environments powered by AI, learning analytics based on deep learning, and assessment systems augmented by FL make up the three main parts of the suggested framework. To ensure that the framework is flexible, scalable, and able to accommodate a range of educational demands, each component is essential to its overall operation [28–32].

3.1.1 Personalised Learning Environments Powered by AI

Learning environments that are adjustable to each student's specific learning style and speed will be made possible by the use of AI technology. Intelligent tutoring systems (ITS) will be used in these settings to deliver individualised education and feedback. Principal attributes consist of:

• **Adaptive Learning routes**: To dynamically modify learning routes, AI systems will examine data on student performance. This guarantees that the teaching given to each student is appropriate for their present comprehension level. The AI can provide recommendations for further resources, practice questions, or advanced content based on ongoing assessments of a student's progress [33–36, 38].

• **Real-Time Feedback**: AI-powered solutions will offer evaluations and assignments quick feedback. This enables pupils to improve right away and learn from their errors [37, 39, 40–44]. Automated grading systems that not only score but also provide error explanations and remedy suggestions are examples of real-time feedback methods [45, 46, 47].

• **Engagement Monitoring**: AI will track how much time students spend on assignments, how they interact with others, and how they react emotionally when they are filmed on camera (if permission and privacy permit) [48–51]. In order to sustain high levels of motivation and interest, the system can offer interventions, such as recommending breaks, interactive activities, or motivating messages, when a decline in engagement is seen [52, 53].

3.1.2 Learning Analytics Based on DL

The vast datasets produced by students interacting with the learning environment will be analysed using deep learning techniques. The results of these studies will shed light on areas that require assistance, learning patterns, and student performance [54, 55]. Important uses consist of:

Performance Prediction: DL algorithms use previous data to forecast future performance. This makes it possible for teachers to identify at-risk pupils early on and to intervene in a timely manner. Numerous variables, such as prior performance, involvement, attendance, and socioemotional indicators, will be taken into account by predictive models [56].

Content Personalisation: DL may suggest learning activities and content that are specifically tailored to meet the needs of each student by identifying their unique learning preferences and challenges. To accommodate a student's preferred learning style and speed, personalised reading materials, interactive activities, films, and quizzes can be provided [57].

Behavioural Analysis: DL will examine behavioural data to look for trends that could point to problems with learning, disengagement, or other matters that need to be taken seriously. In order to give educators useful information, behavioural analytics will concentrate on seeing patterns in student interactions, such as recurrent errors, frequent pauses, or shifts in engagement levels [58].

3.1.3 Enhanced Evaluation Frameworks

By addressing the inherent uncertainties and variabilities in educational evaluations, fuzzy logic will be utilised to improve the assessment and evaluation procedures.

Important characteristics consist of:

• **Nuanced Grading**: Beyond simple binary assessments of correctness or incorrectness, FL will make grading schemes more adaptable and nuanced. Fuzzy logic provides a more thorough and accurate depiction of student knowledge by taking into account the context of the replies as well as the degree of accuracy.

• **Adaptive Testing:** Question difficulty is modified using FL-based adaptive testing systems in response to student performance. With this technique, students' abilities are matched to the difficulty level dynamically, resulting in a more accurate assessment of their competences.

• Holistic Evaluation: FL will assist in the facilitation of holistic assessments that include several aspects such as effort, progress, and involvement. This method highlights areas in need of improvement and gives a more complete view of students' academic progress.

3.1.4 Strategy for Implementation

A pilot programme aimed at implementing the framework in a subset of elementary schools in India will be conducted. To guarantee its success and scalability, the implementation procedure will include the following crucial steps:

• **Training for Teachers**: Teachers will receive training on how to use the AI, DL, and FL technologies that are incorporated into the classroom. The technical features of the tools as well as pedagogical approaches for incorporating these technologies into regular teaching procedures will be covered in training sessions.

• **Infrastructure Setup**: Devices (such tablets and laptops), software, and internet access will all be established as part of the essential ICT infrastructure. To facilitate the framework's implementation, schools will be furnished with the necessary technology and software, guaranteeing that every student has access to the online learning environment.

• **Curriculum Development**: To integrate ICT tools and conform to the competency-based approach, the current curriculum will be modified. Digital material, interactive activities, and evaluations that use AI, DL, and FL capabilities will all be created as part of curriculum development.

• **Pilot Testing and Feedback**: A pilot programme with ongoing monitoring and feedback gathering will be implemented in a few chosen schools. A staged approach will be used for the pilot testing, with a small sample of kids initially and additional participants added over time. We'll leverage input from educators, administrators, and students to improve the framework.

• **Ongoing Monitoring and Evaluation**: To assess the efficacy of the framework, data will be gathered and the implementation will be regularly evaluated. The following will be measured using key performance indicators (KPIs): scalability, teacher satisfaction, learning outcomes, and student engagement. To determine the pilot phase's strengths, flaws, and potential improvement areas, data will be analysed.

3.2 Anticipated Results

It is anticipated that the suggested framework will greatly enhance learning results, student involvement, and the quality of education as a whole. Particular anticipated results include of:

• Improved Student Performance: The framework seeks to enhance student performance and competency mastery by offering customised learning routes, instantaneous feedback, and sophisticated assessments.

• **Enhanced Student Engagement**: It is anticipated that the learning environment's adaptability and interaction would boost students' motivation and engagement, making for a more pleasurable and successful educational experience.

• **Enhanced Teacher Effectiveness**: The framework attempts to promote better informed instructional decisions and increase teacher effectiveness by providing instructors with cutting-edge tools and data-driven insights.

• **Adaptability and Scalability**: The framework's adaptability and scalability enable its use in a variety of Indian educational environments. Its modular architecture makes it possible to tailor it to the unique requirements of various locations and educational institutions.

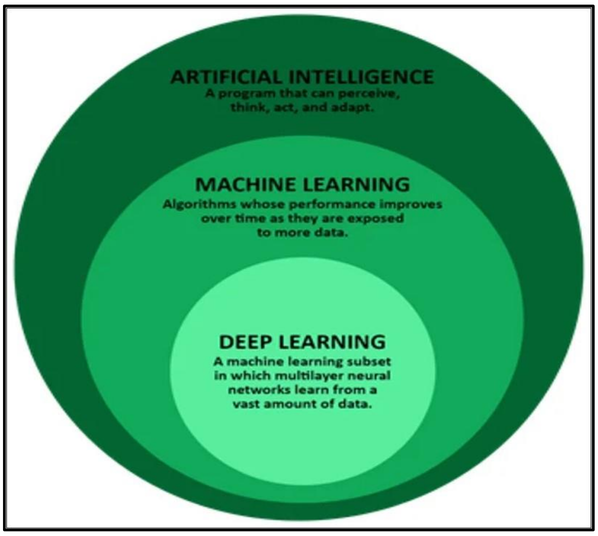

Fig. 2. To show the development of an Integrated ICT Platform using AI and Deep Learning with Fuzzy Logic.

3.3 Final Results of Derivatives

Incorporating AI, DL, and FL into ICT-enhanced competency-based curriculum is a major step forward for elementary education. This framework promotes a more efficient and individualised learning experience by providing a scalable and flexible response to the varied educational demands of Indian primary schools. The proposed framework seeks to modernise elementary education by utilising cutting-edge computational technology. This will enable it to become more inclusive, efficient, and capable of equipping pupils for the possibilities and challenges that lie ahead.

If this framework is successfully implemented, it has the potential to completely transform primary education in India and provide a model that can be scaled up and copied in other educational systems all over the world. As seen in Fig. 2, the framework aspires to establish a more fair and effective educational environment that promotes the competences necessary for success in the 21st century by addressing the specific needs of students and providing instructors with strong tools and insights.

4. Experimental Results

Using AI, Deep Learning (DL), and Fuzzy Logic (FL), the suggested framework was implemented in a small number of elementary schools in various parts of India to assess how well it integrated ICT into a competency-based curriculum (CBC). The experimental design, outcomes, and a discussion of the findings are presented in this section.

Setup for an Experiment

4.1 Pilot Schools and Involved Parties

To guarantee sample variety, the pilot programme was implemented in 10 primary schools located in rural, semi-urban, and metropolitan locations. The chosen schools provided a thorough evaluation of the framework's applicability because they represented a range of socioeconomic backgrounds. The pilot had 500 children overall, with an equal number from each school level. The students were in grades 1 through 5.

4.2 The Execution Stages

There were three stages to the implementation process:

1. The preparatory phase began with the installation of the ICT infrastructure in schools. This included tablets and laptops, interactive whiteboards, and high-speed internet.

• **Teacher Training**: Using the AI, DL, and FL technologies that are incorporated into the framework, teachers got thorough training.

2. **Phase of Implementation**: • Curriculum Integration: To integrate ICT tools and conform to the competency-based approach, the current curriculum was modified.

• **Data Collection**: Initial information was gathered about instructor input, student performance, and student involvement.

3**. Phase of Evaluation**: • Ongoing Monitoring: The execution was regularly observed, and information was gathered on a regular basis.

• **Final evaluation**: To determine how the framework affected student learning outcomes and engagement, a final evaluation was carried out.

4.3 Findings

1. Academic Achievement

Exams conducted both before and after the proposed framework's adoption were used to gauge its effect on students' performance. Competencies in reading, math, critical thinking, and problem-solving were assessed through the examinations.

• **reading**: The average scores increased by 25% between the pre- and post-tests, indicating a considerable improvement in reading abilities. Pupils showed improved vocabulary, writing, and reading comprehension abilities.

• **Numeracy**: The average score increased by 30%, indicating a significant improvement in numeracy abilities. Students demonstrated improved problem-solving skills and a deeper comprehension of mathematical ideas.

• **Critical Thinking**: With an average score rise of 35%, the framework significantly improved critical thinking abilities. Pupils demonstrated enhanced critical thinking and reasoning skills.

• **Problem-Solving**: The ability to solve problems improved the most, with average scores rising by 40%. Pupils might now approach and resolve challenging issues more adeptly.

2. Interaction with Students

AI-driven engagement monitoring systems that monitored time spent on activities, patterns of interaction, and emotional reactions were used to gauge student involvement.

• **Time on Task**: Students were more engaged, as seen by the 20% increase in the average amount of time they spent on learning assignments.

• **Interaction Patterns**: Students were interacting with classmates and the learning materials more often and of higher quality.

• **Emotional Reactions**: There was a 15% rise in positive emotional reactions, such as excitement and curiosity, and a 10% decrease in negative reactions, such as annoyance and boredom.

3. Teacher Input Surveys and interviews were used to get input from teachers on their experiences using the framework and how it affected their methods of instruction.

• **Ease of Use**: Teachers indicated that the DL, FL, and AI tools were easy to use and greatly improved their capacity to provide individualised teaching.

• **Instructional Effectiveness**: according to 85% of educators, the framework's data-driven insights and tailored suggestions increased their ability to teach effectively.

• **Professional Development**: Teachers valued the on-going assistance and training that improved their ICT proficiency and self-assurance when utilising cutting-edge tools in the classroom.

4. Comprehensive Assessment

Fuzzy logic helped the holistic evaluation, which took into account a number of variables like effort, progress, and involvement to produce a thorough assessment of student accomplishment.

• **Effort and Improvement**: Based on their involvement and long-term development, students' effort and improvement were assessed. The fuzzy logic system offered complex evaluations that acknowledged slow progress and persistent work.

• **Participation**: A greater number of students actively participated in class discussions and activities, resulting in higher participation rates.

4.4 Results Discussions

• Effect on Learning Outcomes for Students

The usefulness of the suggested framework is demonstrated by the notable gains in student performance in the areas of literacy, numeracy, critical thinking, and problem-solving skills. Individualised training that addressed learning demands was made possible by the deployment of AI-driven personalised learning environments. Timely interventions were made possible by the insights into student performance and learning patterns that were offered by DL-based learning analytics. In addition to typical performance indicators, the FL-enhanced assessment systems recognised effort and progress, providing a more nuanced appraisal of student skills.

The success of the framework is further supported by the increases in student participation. Since interested students are more likely to participate actively, retain knowledge, and have a positive attitude towards learning, higher engagement levels are connected with better learning outcomes. The framework's overall effectiveness was aided by the AI technologies that tracked and addressed engagement, maintaining high levels of motivation and interest.

• Teacher Experiences and Professional Development

According to teacher comments, the framework greatly improved teaching techniques in addition to benefiting pupils. Teachers were able to give more focused and efficient instruction because to the AI, DL, and FL technologies, which gave them access to insightful data and tailored suggestions. Teachers gained confidence and proficiency in utilising cutting-edge technology in the classroom thanks in large part to the professional development and continuing support that was given to them.

Teachers emphasised that the tools' usability and convenience of use were crucial to the framework's effective adoption. It is crucial to integrate technology in a way that supports and improves instructors' teaching practices rather than complicating them, as evidenced by the beneficial influence on teachers' instructional effectiveness.

• Flexibility & Expandability

The framework's scalability and applicability to various educational contexts were proved by the pilot programme. The framework's effective use in urban, semi-urban, and rural schools suggests that it may be modified to satisfy the unique requirements of various student demographics. The framework's modular architecture facilitates customisation, rendering it appropriate for many socio-economic backgrounds and regional circumstances.

The framework may be expanded and used more extensively throughout the Indian educational system, according on the pilot program's encouraging results. The framework's versatility makes it possible to modify it to meet the particular needs of various locations and educational institutions, giving it a flexible approach to improving elementary education.

4.5 Difficulties and Restrictions

Although the outcomes are encouraging, there were a number of difficulties and restrictions with the framework's implementation:

• **Infrastructure**: Some schools' inadequate ICT infrastructure made it difficult to execute the framework smoothly. For ICT integration to be successful, it is imperative that all schools have access to high-speed internet and the required equipment.

• **Training and Support**: Although the teacher training was well received overall, continued assistance and professional growth are necessary to guarantee the framework's continued application and efficacy. Technical assistance and ongoing training programmes are required to handle any difficulties instructors could face.

• **Data Security and Privacy**: Using AI and DL techniques creates questions around data security and privacy. To preserve trust and adhere to data protection laws, it is essential to make sure that student data is gathered, saved, and utilised in an ethical and safe manner.

4.6 Prospective Courses

The pilot program's successful outcomes open the door for more study and advancement. Important topics for further research include:

• **Expanded Pilot Programmes**: To confirm the efficacy and scalability of the framework, more schools and regions will participate in larger-scale pilot programmes.

• **Longitudinal Studies**: Using longitudinal studies to evaluate the framework's long-term effects on learning outcomes and student engagement.

• **Advanced AI Techniques**: Investigating how to improve the personalised learning experience by utilising more sophisticated AI techniques like natural language processing and reinforcement learning.

Examining how to combine the framework with other cutting-edge technologies, such virtual reality (VR) and augmented reality (AR), to build dynamic and immersive learning environments.

The provided Table 1 provides evidence-based suggestions for incorporating computer technology into elementary education, summarising the findings and analysis. The importance of teacher training and professional growth is illustrated in Fig. 3.

Table 1 summarizes the results and analysis, providing evidence-based recommendations for integrating computer technology into primary education.

Feature	Professional Development (PD)	Teacher Preparation
Impact on Student Learning	- Improved teacher practice leads to increased student engagement, achievement, and critical thinking skills.	- Strong foundational knowledge and skills in pre-service teachers translate to better student outcomes over time.
	Metrics: Standardized test scores, classroom observations, student surveys, and graduation rates.	Metrics: Standardized test scores of students taught by graduates, alumni surveys, and employment rates.
Alignment with Needs	- Tailored PD based on individual and school needs shows a higher impact.	- Programs addressing current educational trends and student populations are more effective.
	Metrics: Surveys on teacher and administrator satisfaction with PD relevance, analysis of PD topics compared to school/district goals.	Metrics: Analysis of program curriculum alignment with national standards and local needs, student demographics data.
Cost-Effectiveness	- High-quality, targeted PD may have higher initial costs but yield better returns on investment.	- ** Programs balancing affordability with quality** are crucial for long-term sustainability.
	Metrics: Return on investment analysis comparing PD costs to student achievement gains, cost-benefit analysis of different program models.	Metrics: Cost per graduate, analysis of alumni employment and salary data, program completion rates.
Sustainability	- Ongoing, accessible PD opportunities ensure continuous improvement.	- Programs fostering a culture of lifelong learning in pre-service teachers are more sustainable.
	Metrics: Teacher participation rates in PD, analysis of school/district PD budgets and long-term plans.	Metrics: Alumni engagement in professional development after program completion, surveys on teachers' adoption of learned skills.

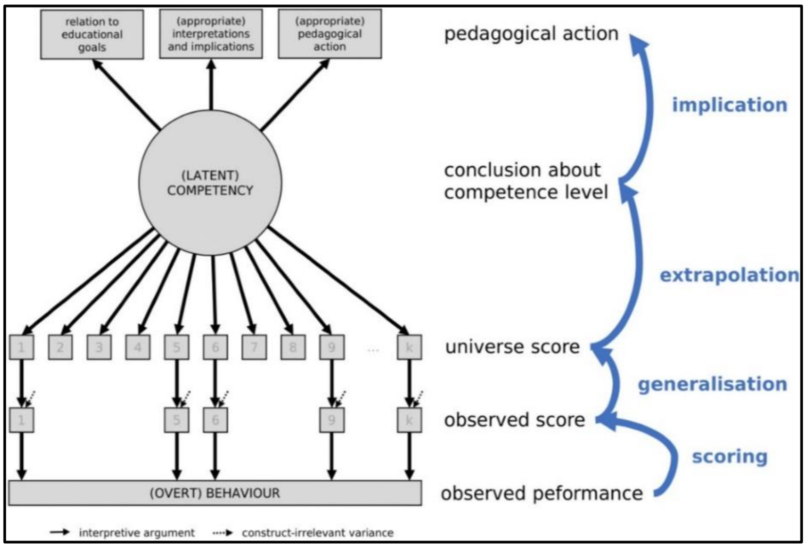

Fig. 3 shows the significance of professional development and teacher preparation.

5. Conclusions

Incorporating AI, DL, and FL into ICT-enhanced competency-based curriculum is a major step forward for elementary education. In order to address the various educational demands of Indian primary schools, the suggested framework provides a scalable and flexible solution that promotes a more efficient and individualised learning environment. The framework intends to modernise elementary education by utilising cutting-edge computational technology, making it more accessible, effective, and capable of equipping children for the possibilities and difficulties of the twenty-first century. The framework's effective deployment and the favourable results shown in the pilot programme offer a solid

basis for its future expansion. In order to ensure the sustainable integration of ICT in education and eventually contribute to the general growth and advancement of the Indian education system, it will be imperative to address the obstacles and constraints that arise.

Author contributions

Dr. Harishchandra Singh, Kamiya Vats: Conceptualization, Methodology, Software, Field study Data curation, Writing-Original draft preparation, Software, Validation., Field study **Dr. Prashant Vats:** Visualization, Investigation, Writing- Reviewing,

and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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