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Adaptability and Innovation of Artificial Intelligence in Educational Contexts: A Conceptual Framework

Prof (Dr) Sajna Jaleel[1], Mariya George[2]

[1]Professor & Head, School of Pedagogical Sciences, M.G. University

[2]Mariya George, Research Scholar, School of Pedagogical Sciences, M.G. University

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ABSTRACT

Artificial Intelligence (AI) is transforming the education sector at a radical pace by providing personalized instruction and by providing simulations to enhance the visualization skills of learners so that teaching-learning process become a fruitful experience. AI in education encompasses Intelligent Tutoring Systems (ITS), AI-based tests and administrative automation. India has started integrating AI into education policies through the efforts of the All-India Council for Technical Education (AICTE) and the National Education Policy (National Education Policy 2020 Ministry of Human Resource Development Government of India, 2020). This research paper aims to analyze AI's impact on education; innovative practices incorporated in educational scenarios as a part of AI-Integration across various disciplines and to design a conceptual framework based on the adaptability and innovation of Artificial Intelligence in educational contexts.

Keywords: Adaptability, Innovation, Artificial Intelligence, Educational Contexts, Conceptual Framework

INTRODUCTION

Information technologies, particularly artificial intelligence (AI), are revolutionizing modern education. AI algorithms and educational robots are now integral to learning management and training systems, providing support for a wide array of teaching and learning activities (Costa et al., 2017, García et al., 2007).Artificial Intelligence (AI) has the potential to address some of the biggest challenges in education today, innovate teaching and learning practices, and accelerate progress towards SDG 4 (*Artificial Intelligence in Education*, 2026). The field of education especially lends itself to AI technologies since educational activities, including learning and teaching, are knowledge-intensive cognitive activities, and AI applications, which are created for cognition and problem-solving based on algorithms and knowledge base, can effectively support and augment educators' and learners' abilities in teaching and learning. Since the advent of AI in the mid-1950 s, AI technologies have been increasingly applied to facilitate education and training in various subjects, including language, STEM, and medicine (Perrotta & Selwyn, 2020). To date, AIED applications are developed to support teaching and learning activities such as content preparation and dissemination, interactions and collaboration, and performance assessment (Chassignol et al., 2018, Perrotta and Selwyn, 2020). This paper explores the dual dimensions of **adaptability**—the capacity of AI systems to adjust to individual learner needs—and **innovation**—the systemic redesign of pedagogy facilitated by AI. We propose the **"Integrated Socio-Technical Adaptability Framework" (ISTAF)**, which categorizes AI integration into three layers: the Micro (Learner), Meso (Institutional), and Macro (Societal).

Research Question

While AI technologies offer unprecedented "personalization," there is a significant gap between technical capability and pedagogical effectiveness. Many AI implementations focus on "automated instruction"—simply delivering content faster—rather than fostering "cognitive autonomy."). While AI offers efficiency, it risks eroding critical thinking through excessive cognitive offloading, where tasks are transferred to AI, weakening

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individual cognitive skills. Without a conceptual framework, innovation remains fragmented, leading to issues of digital inequity and the erosion of critical thinking.

Objectives

- To analyze AI's impact on education;
- To examine innovative practices incorporated in educational scenarios as a part of AI-Integration across various disciplines.
- To develop a conceptual framework (ISTAF) for the ethical and effective deployment of AI.
- To evaluate the shift from AI-assisted teaching to AI-integrated pedagogy.

LITERATURE REVIEW

Impact of AI on Education

AI in student learning

AI-based environments have been used to personalize tasks for student learning. For example, Hirankerd and Kittisunthonphisarn (2020) built an AI-integrated management system with augmented, virtual, and mixed reality technologies to monitor student learning progress for assigning adaptive tasks; Kong et al. (2021) developed a virtual patient for medical student training; Munawar et al. (2018) created and developed an intelligent virtual laboratory to cater for students' needs by assigning laboratory tasks at an appropriate level; and Yang and Shulruf (2019) used an AI-enhanced skin to provide real-time feedback and adaptive tasks to medical students.

Most of the studies implemented AI chatbots and interactive books that allowed students to have conversations with machines about their learning. AI techniques emulate the processes of human thought using structures that contain the knowledge and experience of human experts. AI chatbots and books built with these techniques have been applied to language learning to help students develop their communication abilities through ongoing dialogue (Chew & Chua, 2020; Kim et al., 2021; Koc-Januchta et al., 2020; Palasundram et al., 2019; Vazquez-Cano et al., 2021). Another common use of AI has been to give students timely guidance and feedback by analyzing their work and learning process (Fu et al., 2020; Porter & Grippa, 2020). For example, Bonneton-Botte et al. (2020) used an AI application for notebooks to recognize and acquire kindergarten students' handwriting and then analyze its spatiotemporal characteristics (i.e., the shape, order, and direction of the segments). The application gave feedback to the students at the end of each writing session. Vahabzadeh et al. (2018) used AI-enabled smart glasses to improve the attention of autistic students by monitoring their socially aware emotions and behavior.

AI technologies have been implemented to capture student learning data and facilitate interactions for more adaptive digital environments. For instance, Samarakou et al. (2015) developed an advanced e-learning enviroment for engineering students. Kickmeier-Rust and Holzinger (2019) designed and developed a combinatorial optimization algorithm (the MAXMIN ant system) that was useful and effective in adaptive games. Westera et al. (2020) used techniques, such as facial emotion recognition, automatic difficulty adaptation, and stealth assessment, to profile students and applied techniques, such as non-verbal bodily motion and lip-synchronized speech, to develop non-playing characters. The student profiles and characters enhanced the adaptability and interactivity of learning.

Intelligent tutoring systems aim to recommend teaching content and tasks that are appropriate for teaching needs (Aldeman et al., 2021; Bellod et al., 2021; McCarthy et al., 2016; Weragama & Reye, 2014). For example, Luo (2018) and Standen et al. (2020) adopted AI systems using multimodal sensor data to identify students' affective statuses and help teachers determine the optimal presentation of content, teaching methods, and communication strategies. Lampos et al. (2021) used an AI classifier to recommend effective communication strategies for teachers to teach autistic students by analyzing student responses and attributes. In the study of Crowe et al.

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(2017), teachers adjusted their teaching strategies based on the instant feedback provided by an academic writing software package on individual and whole class processing of learning material.

The combination of computer assisted instruction and AI technologies has been applied to helping teachers manage their classroom teaching (D. Yang, Oh, & Wang, 2020; Jaiswal & Arun, 2021; Nabiyev et al., 2013; Wang & Zheng, 2020; Zhang, 2021a, Zhang, 2021b). AI technologies have been used to support teaching in different subject classrooms (e.g., physical and language education) by efficiently uploading, assigning, and distributing learning materials and assignments and by speaking out text-based problems. These applications have greatly improved the efficiency of classroom management for teachers (Gupta & Bhaskar, 2020; Huang et al., 2021; Jarke & Macgilchrist, 2021; Rapanta & Walton, 2016).

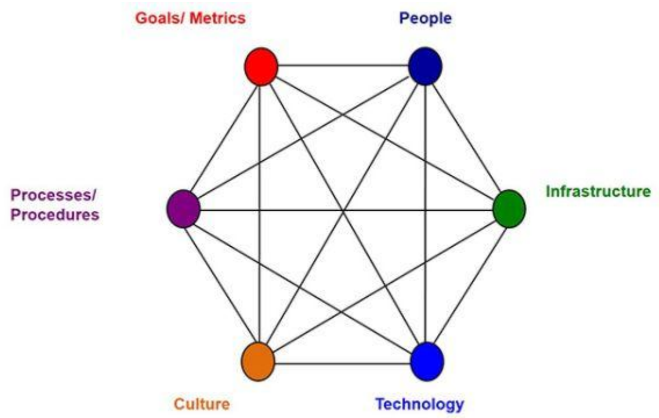
AI technologies have been applied not only to support teaching but also to support the professional development of teachers (Gunawan et al., 2021; Lampos et al., 2021). In these studies, teachers were given suggestions and comments on their teaching by AI agents that analyzed real-time data in classrooms, such as behavior and questioning skills, and teachers' responses to diagnostic tests of their pedagogical content knowledge. Teaching evaluation models have also been built from teaching data (Hu, 2021; Li & Su, 2020).

Analysis showed that the use of AI to enhance and automate assessment resulted in more effective grading (Aebi & Karal, 2017; Alghamdi et al., 2020; Fu et al., 2020; Kumar & Boulanger, 2020; Ma & Slater; 2015). AI-enhanced grading systems for language writing and speaking and mathematics provided more accurate, fast, and secure grading in tests and examinations than teachers. The systems were also able to return immediate marks for formative feedback in online learning.

AI technologies appear to have assisted in predicting student performance, particularly in online education (Akmese et al., 2021; Costa-Mendes et al., 2021; Yu, 2021). They have shown a capacity to predict students' performance in online courses by assessing the extent and quality of their participation in learning activities, such as discussion forums. This functionality is very important for distance education and MOOCs due to the absence of teachers. However, selecting data for prediction is challenging. Costa-Mendes et al. (2021) argued that the student data used for classic statistics may not fit AI predictive models.

CONCEPTUAL FRAMEWORK (ISTAF) FOR THE ETHICAL AND EFFECTIVE DEPLOYMENT OF AI.

With a strong theoretical base on Socio-Technical Systems Theory, Integrated Socio-Technical Adaptability Framework" (ISTAF) categorizes AI integration into three layers: the Micro (Learner), Meso (Institutional), and Macro (Societal). Within a socio-technical systems perspective, any organisation, or part of it, is made up of a set of interacting sub-systems, as shown in the diagram below.



Socio-technical theory has at its core the idea that the design and performance of any organisational system can only be understood and improved if both 'social' and 'technical' aspects are brought together

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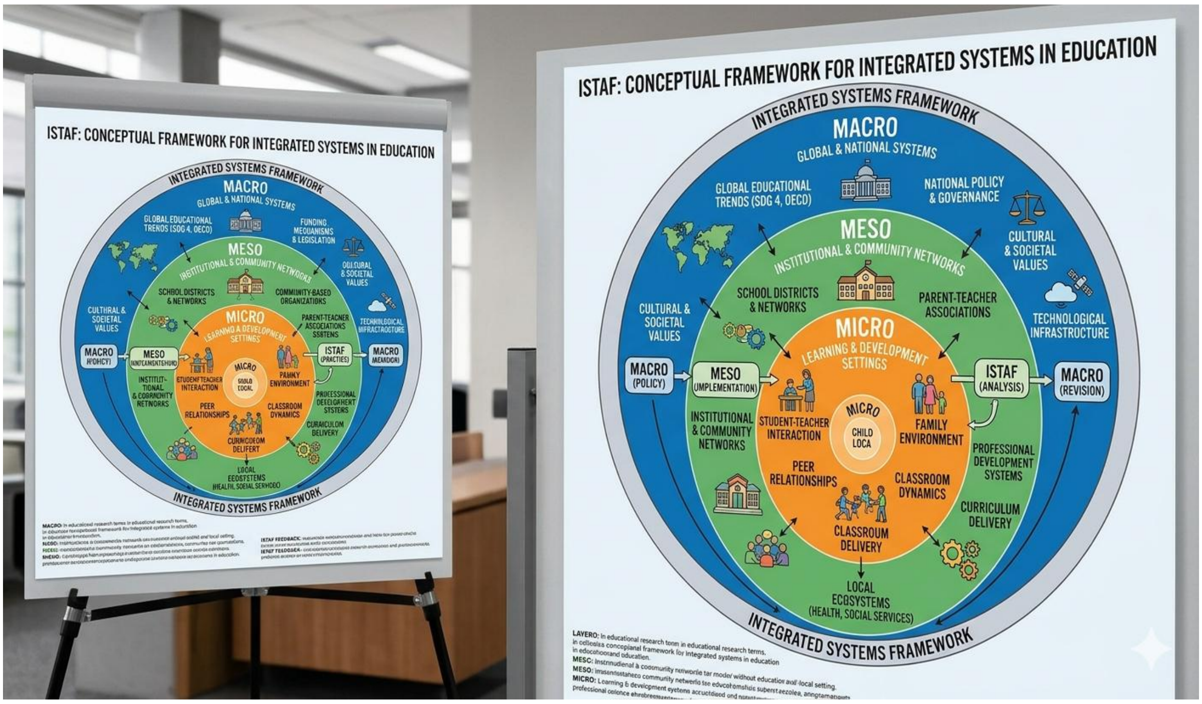
and treated as interdependent parts of a complex system. Socio-Technical Systems Theory (STST) offers such a perspective by conceptualizing organizations as dynamic configurations of interacting technical and social subsystems whose ongoing negotiation and adaptation fundamentally shape the outcomes of technological innovation (Bostrom & Heinen, 1977; Mumford, 2006; Pasmore et al., 2019; Trist & Bamforth, 1951). Rather than treating technology and organization as isolated variables, STST views innovation as an emergent, processual phenomenon in which changes to AI systems are intertwined with evolving work routines, governance mechanisms, data infrastructures, and decision-making practices (Akter et al., 2022; Cannas, 2023; Chaudhuri et al., 2024; Pfaff et al., 2023).

Integrated Socio-Technical Adaptability Framework (ISTAF) categorizes AI integration into three layers: the Micro (Learner), Meso (Institutional), and Macro (Societal). The Integrated Socio-Technical Adaptability Framework (ISTAF) conceptualizes AI as a multi-layered socio-technical ecosystem in which successful integration depends on the adaptive alignment of human, technical, institutional, and systemic elements across micro, meso, and macro layers.



Layer 1: Micro AI Layer (User level)

This layer points to the use of various AI tools, personalized tutoring AI, AI writing support, AI feedback systems, AI productivity tools, AI for problem-solving by students, teachers, faculty, administrators and learners across various disciplines. Adaptability Constructs at this layer encompasses cognitive adaptability, digital adaptability, AI self-efficacy and ethical adaptability.

Layer 2: Meso AI Layer (Institutional/Organizational Level)

This layer emphasizes upon AI as embedded in institutional structures and practices. The core focus at this layer includes LMS-Integrated AI, AI-enabled assessment systems, institutional chatbots, AI-supported teaching design and AI analytics for student monitoring. Socio-technical focus at this layer happens in the form of interaction between institutional culture, infrastructure, governance, and pedagogical integration. Adaptability Constructs at this layer consists of institutional adaptability, curriculum adaptability and organizational readiness.

Layer 3: Macro AI Layer (Provider/ Policy/Ecosystem Layer)

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AI as part of a broader ecosystem shaped by providers, regulation and policy. AI at this layer act as a large AI platform and policy-guided AI ecosystems. At this layer, socio-technical focus specially points to the interaction between regulation, accessibility, affordability, sustainability and equity. Adaptability Constructs at this layer includes systematic adaptability, policy adaptability and ecosystem resilience.

RESULTS/DISCUSSION

Even though AI has far and wide- reaching applications as mentioned in the Review of Related Literature across student learning, teaching and assessment, there are certain points to be addressed as selecting appropriate data for student performance predictive models remains challenging as the data are not the same as those used in traditional educational research, without a grasp of the mechanism of task assignment and teaching strategy recommendations, teachers have reported feeling that their control was diminished and that they were working with a black box. The resulting decline in self-efficacy may discourage teachers from using AI to support their classroom teaching. The study throws light into a conceptual framework (ISTAF) through which AI -integration across disciplines become sustainable and educationally meaningful when AI is understood as a three-layer socio-technical ecosystem in which adaptability operates across individual, institutional, and provider-policy levels.

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