LEADING EDUCATIONAL PARADIGM CHANGE THROUGH GenAI INTEGRATION: A NOVEL 4E FRAMEWORK FOR K-12 SPACE

Muhammad Jamil[1], Shafiq Hussain[2], Muhammad Farhan[3]

Abstract

Generative AI (GenAI) strengthens education, but large-scale adoption faces numerous challenges. Pilot research projects show some assurance, but a framework is required for school-wide implementation. Managing stakeholders, ethics, assessment and inequity in implementing the program is essential for 21st-century pedagogy. Several frameworks provide initial guidance, but more iterative experimentation and feedback cycles should be needed. In this research, we proposed a 4E (Explore, Engage, Elaborate and Evaluate) educational framework to implement GenAI in K-12 spaces. The exploration phase entailed presentations to obtain administrative approval. A committee sets the standards and the teacher training process in the engagement phase. We conducted experiments in five classes to integrate GenAI tools for kids learning. In each phase, we performed evaluations using student and teacher surveys. The exploration phase gained support, and the engagement phase set the guidelines and prepared instructors. The explore phase showed engagement and knowledge gains. The evaluation phase through surveys and feedback informed elaborations and mainstreaming successes. Our research findings provide a reflectionable model of phased introduction, with education for addressing challenges through a categorized standard. This revolutionizes the teaching and learning process in the digital technology world.

Keywords: *Generative AI, education, pedagogy, 4E educational framework, digital technology*

Introduction

Human learning is a process that changes the human mind, creates new ideas and develops the foundations of society. With the help of advancements in artificial intelligence (AI) and machine learning (ML), generative (GenAI) now become a significant source of generating AI content, including but not limited to text, images, audio and videos. Incorporating GenAI in education has been considered one of the most promising trends nowadays [1]. For instance, in course design, evaluation tools and techniques, and students' participation, GenAI is a game changer. GenAI not only helps the learners to get learner-centred learning material but also helps educators to perform automated grading and feedback and generate practice materials and assessments with the help of rubrics. GenAI is a type of AI system which can create new text, images, audio, and videos with the help of large language models (LLMs) like GPT, Claude, Llama, Gemini, PaLM, Falcon, and BERT. From the above, GenAI presents a promising future in education by improving teaching and learning processes through personalized instruction, automation of routine tasks, and intelligent tutoring systems. However, changing the pedagogy through integrating GenAI across society has its impediments [2].

Current work has mainly involved small-scale studies to pilot GenAI for instructional purposes. The pilot projects show potential in this area. However, a more structured approach is necessary

[1]Department of Computer Science, COMSATS University Islamabad, Sahiwal Campus, Pakistan. jamil138.amin@gmail.com

[2] Department of Computer Science, University of Sahiwal, Pakistan. drshafiq@uosahiwal.edu.pk

[3] Department of Computer Science, COMSATS University Islamabad, Sahiwal Campus, Pakistan. farhansajid@gmail.com

to bring in all the necessary parties and ensure the long-term integration of GenAI in teaching and learning across all schools. Earlier research [3] offered the first step but did not propose how to manage the experiment and feedback loop needed for scaling up the GenAI in education. In light of this, this research intends to fill this gap by proposing and implementing a novel 4E (Explore, Engage, Elaborate, Evaluate) framework for the phased implementation of GenAI-enhanced teaching and learning practices in the K-12 space. An exploratory case study employs the 4E framework in a K-12 school-based setting. All the phases are qualitatively reviewed to determine the framework's performance and learn the best evaluation practices.

Thus, this research offers significant findings to the growing literature on AI's role in the education shift. In this regard, it tries to map out a process that, based on stakeholder feedback, can steer through the potential chaos of large-scale change and harness the potential of GenAI to revolutionize teaching and learning in the digital age. The implications provide valuable recommendations for educational organizations worldwide that wish to exploit new technology effectively.

This paper is organized as follows: Section 2 contains the literature review about the educational technology adoption frameworks and GenAI applications. Section 3 presents the methodology applied in applying the 4E framework. Four stages of implementation are discussed in detail and analyzed with qualitative data and findings in Section 4. The last section, Section 5, assesses the overall performance of the framework. In Section 6, the governance best practices and the future research directions are summarised.

Literature Review

A recent literature review [4] focused on using GenAI in language teaching and learning. The review focused on papers published from 2017 to 2023 and talked about GenAI tools such as GPT-3. Some of the critical issues that were identified include the terms used in the area of research, the most used languages and education levels in GenAI research, the areas that have been explored on GenAI, the perceptions of people on the use of GenAI, and the opportunities and risks that come with the use of GenAI. Some of the gaps identified include the need for more research on GenAI's performance, ethical concerns, language skills-based interventions, and involvement of stakeholders in the proper integration of GenAI. Overall, the review helps to establish and elaborate on GenAI's current position in language education and to outline further research implications in this continuously developing area. As one of the most recent and famous examples of GenAI, the authors of [5] talked about how ChatGPT can be useful for preservice and novice teachers. The paper also embraces GenAI's capacity to write essays and finish assignments, which is a significant concern of plagiarism if applied by the students in the wrong way. However, it also draws attention to how GenAI has the potential to handle repetitive tasks and thus save time for teachers. Some university instructors are changing their lectures to fit the GenAI tool or assessments in some way, while others are concerned about its impact on critical thinking. In her paper, Clarke explains how school librarians are in a position to help teachers and students know when and how to apply GenAI and help mitigate the risks by setting policies

that may suit them. From this research, it is possible to identify opportunities and threats of GenAI adoption that underpin the framework described in the current work.

In a recent paper by [6] discussed strategies for appropriate application of generative AI (GenAI) tools like ChatGPT and the forthcoming Google Gemini in the educational context. The paper highlights that GenAI can modify how learning takes place. However, simultaneously, the authors argue that there is a need to embrace the use of GenAI most ethically, as it aligns with the proposal by Smith et al. The authors of the paper want to examine how different stakeholders view current and future GenAI systems in the context of learning and develop a set of guidelines that would address issues that are likely to arise as well as the ethical considerations of the use of GenAI system as pointed out by the authors. They also state that the holistic approach will enable the policymakers to design change and harness all the advantages of AI without compromising learners' health and academic honesty, as noted by the authors. This research is relevant to the present study since it identifies the need to engage all stakeholders and consider multi-dimensional effects when creating governance models for educational technology use, as described in the same work. The authors of [7] surveyed pre-service teachers to learn about their use of and attitudes toward generative AI applications. Their research identified vital factors influencing views and revealed opportunities for further integrating GenAI tools into learning and teaching processes to support pre-service educators.

The authors of [8] and [14] described the opportunities for learning and utility for teachers who work in K-12. The authors described how teachers modified their teaching practices and the number of hours worked in light of GenAI. However, this may be threatened by challenges that may arise in the course of integration. The current and future GenAI classroom requires reliable and robust internet and the latest sound devices. The teachers must be better equipped with technical know-how to apply the GenAI content appropriately. This gap takes some time to close since teachers need to be trained to choose and implement these GenAI supplements into their teaching practice. Table 1 shows a summary of recent research on the application of GenAI in education.

Table 1. Key Insights from Research on Generative AI in Education

Sr. No.	Ref. No.	Year	Major Contribution	Research Challenges	Future Direction
1	[9]	2024	The authors investigated the application of GenAI in language education, demonstrating its effectiveness in improving language learning outcomes and increasing student satisfaction.	Limited research on the long-term impact of GenAI on learning outcomes.	There is a need of ethical implications, and expanding the use of GenAI in other educational settings.

2	[10]	2024	Analyzed the integration of DALL-E 3 and ChatGPT for generating science education imagery, highlighting both the potential and risks of GenAI in reinforcing stereotypes in science education.	Issues of bias, transparency, and reinforcement of stereotypes in AI-generated images.	There is a need to explore more diverse representations of GenAI content in educational institutions.
3	[11]	2024	Proposed a conceptual design for a GenAI system that personalizes learning by generating tailored content, feedback, and assessments based on each student's needs.	Challenges include integrating GenAI systems into existing educational frameworks, addressing ethical concerns, and ensuring privacy and security.	Further research needed to develop detailed guidelines for implementing GenAI systems at the institutional level and to address ethical and legal issues.
4	[12]	2023	Provides an overview of Generative AI's potential impact on classroom practices, including personalized learning and teacher workload reduction.	The need for adequate teacher training and equitable access to AI tools.	There should be a mechanism that support teacher training in GenAI.
5	[13]	2023	Conducted a systematic review and bibliometric analysis of GenAI in education, identifying key themes such as AI-powered chatbots, large language models (LLMs), and their impact on teaching and learning.	Challenges include lack of emotional intelligence in AI, and the need for AI literacy and prompt engineering skills among educators and students.	There is a need to improve GenAI literacy, and developing skills in prompt engineering to maximize GenAI educational potential.

Research Methodology

This work used a sequential exploratory design to design and pilot a 4E (Explore, Engage, Elaborate, Evaluate) framework for GenAI tools in K-12 education. We provided hands-on training on the role of prompt engineering to research participants of the local school and then

asked the participants to fine-tune the GenAI models using custom prompts. Table 1. Shows a variety of custom prompts designed to fine-tune GenAI models for generating precise and informative responses in subjects such as computer, science, geography, history, mathematics, and physics.

Table 1. Custom Prompts for Fine-Tuning GenAI Models Across Various Educational Subjects

No.	Prompt Type	Custom Prompt	Expected Output
1	Basic Concept Explanation	"Explain the different generations of computers and their key characteristics."	A detailed explanation of the different generations of computers (1st to 5th), including their technologies, key features, and examples.
2	Shortcut Functionality	"What is the shortcut key for 'Copy' in MS Excel, and what does it do?"	The shortcut key (Ctrl + C) for 'Copy' in MS Excel and a description of its functionality.
3	Concept Understanding	"Describe the concept of 'Plate Tectonics' in geography using simple language."	An easy-to-understand explanation of 'Plate Tectonics', highlighting how Earth's plates move and interact, and their impact on natural phenomena like earthquakes and volcanoes.
4	Step-by-Step Guide	"List the steps to create a pie chart in MS Excel using the sample data provided."	A step-by-step guide to creating a pie chart in MS Excel using the sample data.
5	Comparison Inquiry	"Compare and contrast the concepts of mean and median."	A comparison outlining the differences and similarities between the mean and median, including their definitions, how they are calculated, and their use cases.
6	Definition Request	"Define 'Artificial Intelligence' in simple terms suitable for a 6th-grade student."	A straightforward definition of Artificial Intelligence tailored for a 6th-grade student's understanding.
7	Advanced Concept Simplification	"Simplify the concept of 'Quantum Computing' for a high school student studying computer science."	A simplified explanation of 'Quantum Computing' suitable for a high school student.
8	Scientific Concept	"Explain the process of photosynthesis in simple terms for a 5th-grade	A simple explanation of photosynthesis suitable for a 5th-grade student.

	Clarification	student."	
9	Chemistry Reaction Description	"Describe what happens during a neutralization reaction between an acid and a base."	A detailed description of a neutralization reaction, including the products formed and an example reaction.
10	Physics Calculation Example	"Calculate the kinetic energy of an object with a mass of 10 kg moving at a velocity of 5 m/s."	The calculation and result of the kinetic energy of an object based on the given mass and velocity.

We implemented a 4E framework (Explore, Engage, Elaborate, Evaluate) incorporating GenAI in the K-12 space. The exploration phase started with interviews with school administrators to get their impressions and obtain an administrative buy-in for the project. Then comes the engagement phase, which includes the formation of a committee to establish standards and give detailed GenAI training to the teachers. The focus group discussions established the particular needs and challenges likely to be encountered in integrating AI tools in the classroom. According to the above findings, the training and tools were adjusted where required. The Elaboration Phase was an attempt to test the GenAI tools in some classroom settings, and student assessments were made to determine the effects of these tools on learning. Last was the Evaluation Phase, which entailed an assessment of the learning outcomes to evaluate the usefulness of the GenAI tools. Depending on the results obtained, the framework was either maintained and further employed to realise GenAI in educational contexts or modified to enhance the process. Figure 1 shows the flowchart of the 4E Framework for Implementing GenAI in K-12 space.
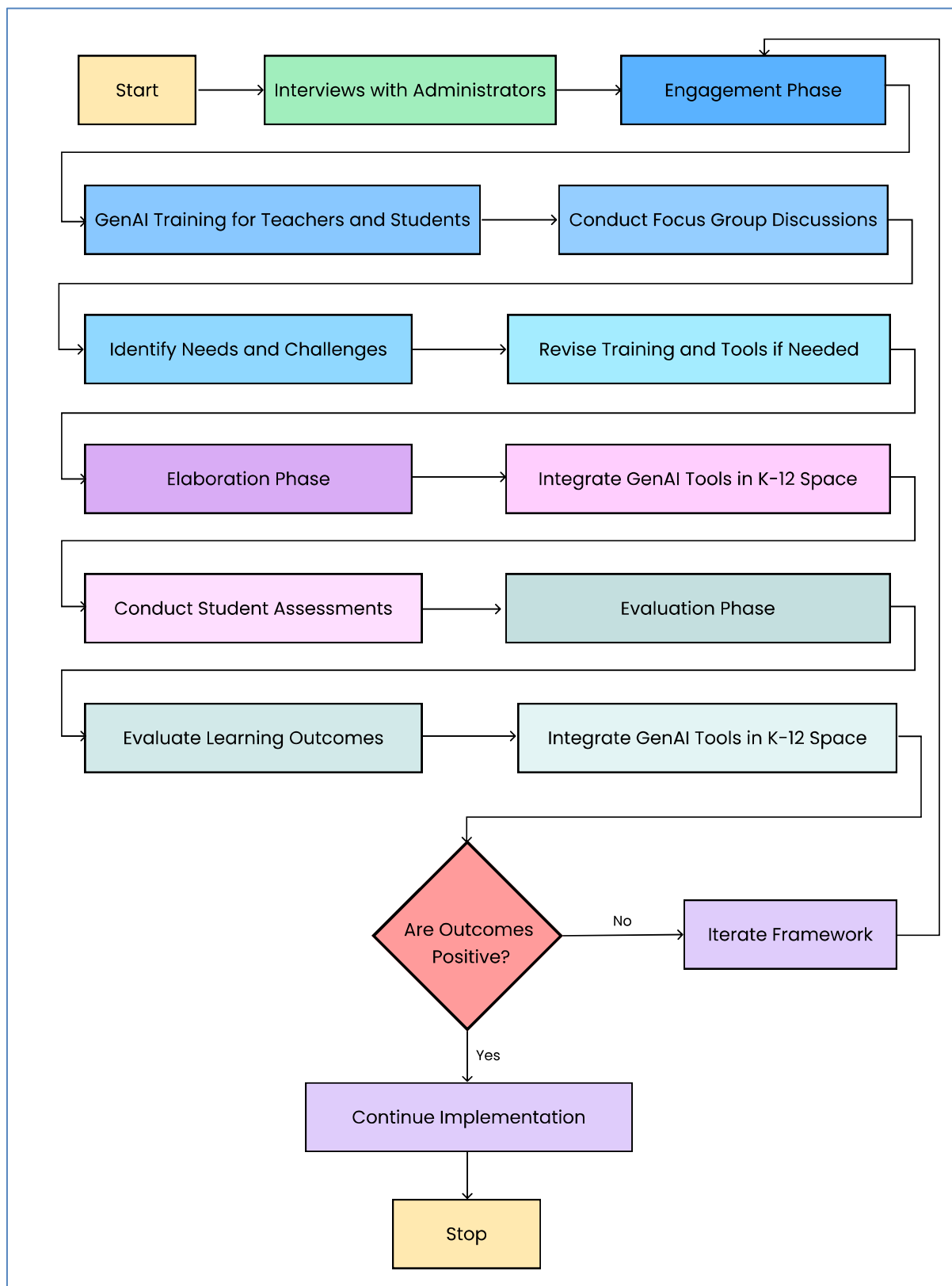
Figure 1. Research Flowchart

Exploration Phase

Interviews were carried out with five respondents, who are school administrators, to gain their perception of the implementation of GenAI. The interviews were conducted for about 30 minutes, and all the interviews were audiotaped with consent from the participants. The interviews were later audiotaped, and the tapes were transcribed word by word. These included an interview guide with loose questions on the possible benefits and difficulties of GenAI, the preparedness of the school and the implementation plan. The data was coded to arrive at themes that were dominant in the conversation.

Engagement Phase

Altogether, 30 teachers in different fields were interviewed in ten focus group discussions. All focus group discussions were conducted with 3 participants, each taking 60 minutes. The interviews were conducted based on questions that aimed at identifying the participants' perceptions of the following topics: How would you incorporate GenAI into lessons? What support and training do teachers need to incorporate GenAI into lessons effectively? What considerations should be made when developing guidelines for using GenAI in lessons? All the discussions were recorded, transcribed, and analyzed by identifying the themes. Furthermore, a self-developed 30-item questionnaire with a 5-point Likert scale was distributed to 50 teachers to gather quantitative data.

Elaboration Phase

The 7 classes, which resulted in 100 students, were selected to pilot the GenAI tools. We guided them about the prompt engineering and they tried to learn the topics of different subjects. The sample comprised students in grades 6-12, and the study was conducted voluntarily and with the permission of the parents and guardians of the students. The study employed a pre-and post-test design, and students filled out a 20-item survey before and after the six weeks of intervention.

Evaluation Phase

The remaining 5 administrators and 10 teachers from each subject area pilot school were administered semi-structured interviews. A 10-item survey was also distributed to collect numerical data from the participants. Qualitative data were analyzed using content analysis, while quantitative data were analyzed using the IBM SPSS tool. Quantitative data collected was tabulated and analyzed, while qualitative data was analyzed through content analysis. When appropriate, the independent sample t-tests and one-way ANOVA were used. The framework's validity was ensured by comparing the study outcomes with the 4E framework. The school ethical committee cleared all the procedures. Table 2 shows a summary of our interviews.

Table 2. Summary of Interviews and Focus Groups on Incorporating GenAI in Education

Interview/Focus Group	Details	Themes Discussed/Views Expressed

Teacher Interview 1	Age: 38 Subject Taught: Science Years of Experience: 12	• Benefits student learning through individualized explanations • Can reduce teacher workload by answering basic questions • Concerned about tech issues disrupting lesson flow • Wants training on using AI tools effectively in the classroom
Teacher Focus Group 2	Participants: 2 females, 1 male (ages 30-45) Subjects Taught: Math, Computer, Geography, Physics, Chemistry, General Science	• GenAI makes lessons more interactive and engaging • Tools should supplement not replace teacher-student interaction • Training is needed, especially for older teachers less tech-savvy • Guidance required on addressing potential student misconceptions from AI
Administrator Interview 3	Gender: Male Years as Principal: 8	• Budget constraints a challenge for large-scale AI integration • Supports phased pilot program to demonstrate benefits first • Teachers will require ongoing pedagogical support for new approach • Important AI doesn't exacerbate existing equity issues for some students
Student Focus Group 4	Participants: 5 students (ages 14-16) Subjects Studied: Various	• Finds GenAI helpful for understanding difficult concepts • Enjoys interactive learning features • Concerns about reliance on AI for homework help • Prefers a balance between AI use and traditional teaching methods

Results and Discussion

Teacher Perspectives

In order to explore the use of Generative AI in the classrooms in-depth, interviews with individual teachers were conducted, and significant observations were made. Teachers shared a

high level of confidence that GenAI can help students learn with individualised explanations that can be given to each learner. This is very useful in enhancing learning as opposed to traditional teaching methods. Moreover, teachers expect that GenAI will help them free up some time, as it will answer basic questions and perform basic tasks, otherwise consuming teachers' time. However, there needs to be more reliability in technology in the classroom setting. The teachers are concerned that technical problems may occur during the class that may interfere with the smooth process, which in turn affects the learning process. In addition, there is a high need for specific training on how to apply AI equipment. It is critical to note that teachers need more support to incorporate these technologies into their teaching practice.

Teacher Focus Group Perspectives

The following are the observations from the focus group of teachers on the effect of GenAI on lessons and students' participation. People agreed that through AI tools, classroom lessons can be more lively and engaging, improving the learning process. However, all these benefits must be used to enhance the teacher-learner relationship, so there is a general notion that GenAI should be used in the classroom to complement teacher-student interactions. The focus group also pointed out the need for training, which is more acutely felt in the case of older teachers who may not be well-versed in the use of technology. This training should include integrating AI while ensuring that the students get more of the teacher's time. Also, the focus group highlighted the need to be advised on dealing with possible misunderstandings that the AI-produced content may bring about. Therefore, students must be able to comprehend and make proper sense of the information given to them by AI tools.

Administrator Perspectives

Some of the issues raised by the administrators about the large-scale adoption of GenAI included. The funding is a significant hindrance to implementing AI in the education system. The managers also approved a step-by-step approach to AI integration, initially focusing on testing the new technology in small sections and demonstrating its positive effects. This step-by-step approach enables the identification of the effectiveness or otherwise of the strategies and makes necessary changes. Furthermore, several administrators know the need to sustain pedagogical assistance for teachers as they adopt new AI applications. Another important consideration is how it will maintain the current equity situation. School administrators are currently paying attention to the need to ensure that all the students are equally placed while at the same time incorporating the latest technologies.

Conclusion

This study provided a 4E (Explore, Engage, Elaborate, Evaluate) model for how GenAI can be incorporated into K-12 education to manage the use of AI tools in the classroom effectively. The study shows how GenAI can improve the teaching and learning experience through personalised content, interactive engagement and automation of administrative activities. It was found that GenAI has the potential. However, there is a need for proper training and preparation of the teachers and issues related to ethics, equal opportunity, and follow-up support. This paper

presents a 4E model for a step-by-step implementation process that begins with administrative approval, then standard development and teacher preparation, then implementation in the classroom and finally, evaluation based on the collected data. As the pilot phase of the framework has proven to be effective in increasing the students' engagement and knowledge, the framework's usefulness in other settings can be expected.

Future research should examine the applicability of the 4E framework in a variety of educational settings in order to assess the generality of the 4E framework. Moreover, it could also look for the long-term effects on student achievement, teacher's time, and school performance. There are also gaps in creating a set of guidelines that can help with the ethical issues raised, data privacy issues, and the proper application of the AI tools. That is why, in addition to teachers and students, policymakers and parents should be involved in fine-tuning the approach and expanding it in a way that is congruent with the purpose of education and the values of society.

References

[1] Meli, "Empowering educators with generative ai: The genai education frontier initiative," *EDULEARN24 Proceedings,* 2024.

[2] Pantazatos, "GENERATIVE AI THROUGH THE TEACHER'S LENS: PERSPECTIVES ON ADOPTION IN SCHOOL EDUCATION," *EDULEARN24 Proceedings,* 2024.

[3] S. a. K. R. a. S. A. Shailendra, "Framework for Adoption of Generative Artificial Intelligence (GenAI) in Education," *IEEE Transactions on Education,* 2024.

[4] L. Law, "Application of generative artificial intelligence (GenAI) in language teaching and learning: A scoping literature review," *Computers and Education Open,* pp. 100-174, 2024.

[5] E. a. W. H. GROSS, "School Librarians as Collaborators in the Successful Use of GenAI," *Exploring New Horizons: Generative Artificial Intelligence and Teacher Education,* p. 145, 2024.

[6] P. Perera, "Preparing to revolutionize education with the multi-model GenAI tool Google Gemini? A journey towards effective policy making," *Journal of Advances in Education and Philosophy,* 2023.

[7] M. a. S. L. a. N. M. a. Z. X. a. K. P. a. A. S. A. a. A. B. N. Nyaaba, "Generative AI as a Learning Buddy and Teaching Assistant: Pre-service Teachers' Uses and Attitudes," *arXiv preprint arXiv:2407.11983,* 2024.

[8] K.-J. a. A. J. Laak, "Generative AI in K-12: Opportunities for Learning and Utility for Teachers," *International Conference on Artificial Intelligence in Education,* 2024.

[9]   S. a. V. S. a. A. Z. Jadhav, "Bridging the Gap: Exploring the Revolutionary Application of GenAI in Language Teaching and Learning," *Journal of Electrical Systems,* 2024.

[10] G. a. T. K.-S. Cooper, "Pixels and Pedagogy: Examining Science Education Imagery by Generative Artificial Intelligence," *Journal of Science Education and Technology,* 2024.

[11] L. Bonde, "A Conceptual Design of a Generative Artificial Intelligence System for Education," *International Journal of Research and Innovation in Applied Science,* vol. 9, no. 4, pp. 457-469, 2024.

[12] A. Pons, Generative AI in the classroom: From hype to reality, London: OECD Publishing, 2023.

[13] A. Bozkurt, "Unleashing the potential of generative AI, conversational agents and chatbots in educational praxis: A systematic review and bibliometric analysis of GenAI in education," *Open Praxis,* vol. 15, no. 4, pp. 261-270, 2023.

[14] Y.-C. a. C. Y.-H. Hsu, "Generative artificial intelligence in education, part one: The dynamic frontier," *TechTrends,* vol. 67, no. 4, pp. 603-607, 2023.