Fostering AI Literacy: A Survey of Student Perceptions and Effective Practices in K-12 Machine Learning

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***Abstract*— This research addresses the integration of Machine Learning (ML) into K-12 education, which is increasingly recognized as essential for preparing students for the AI-driven world. However, the current landscape of ML implementation and its impact in K-12 classrooms remain areas of active investigation. In recent years, the integration of ML techniques into K–12 computing education has become increasingly prevalent, reflecting the growing importance of AI-driven and data-driven approaches across computing fields. This study addresses the gaps in understanding how intuition and agency develop in the context of ML systems within K–12 education, while also examining the emerging trajectories, challenges, and opportunities in teaching ML in K–12 education. Motivated by the need to assess the effectiveness and challenges of ML integration in K-12 settings, this survey-based study aims to provide insights into pedagogical approaches, tools utilized, and teachers' perceptions of ML in education. Drawing upon the importance of early ML exposure in developing computational thinking and fostering data literacy, this study seeks to address gaps such as age-appropriate content, teacher preparedness, and ethical considerations. By systematically reviewing existing research and surveying educators, this study aims to offer valuable insights into effective practices, identify tools available, and highlight areas for further research on the responsible implementation of ML in K-12 settings. Furthermore, this study emphasizes the importance of understanding gender-based differences in ML education. It briefly presents gender-based results obtained from surveys and data analysis, suggesting the need for tailored approaches to ML education that address potential gender-based barriers and biases. Additionally, the study discusses the paradigm shift required to successfully integrate ML into K–12 computing curricula, advocating for embracing ML as a fundamental component of future computing education. Ultimately, this study aims to inform computing educators and policymakers about the challenges and opportunities associated with ML education in K–12 settings, laying the groundwork for fostering ML literacy and computational thinking skills among K–12 students.**

Keywords*— *CS Success, Education, K-12, Machine Learning

I. Introduction

The expanding role of artificial intelligence (AI) in daily life and the potential societal changes it brings are driving a global interest in AI education. Central to this interest is the recognition that machine learning (ML), a subset of AI, is at the core of most AI advancements. ML algorithms enable systems to learn from data, identify patterns, and make decisions with minimal human intervention. This capability powers technologies like face recognition systems, chatbots, recommendation algorithms for social network connections, and even autonomous vehicles.

These applications offer intriguing possibilities for educational settings. Introducing children and young adults to these technologies early can significantly enhance their comfort and proficiency with these tools, enabling them to better understand and utilize them in the future. ML-based tools can enrich various aspects of K-12 education, from personalized learning experiences to intelligent tutoring systems that adapt to individual student needs. By integrating ML into the curriculum, educators can provide students with valuable skills in data analysis, problem-solving, and critical thinking, which are increasingly essential in the AI-driven economy.

The research on AI and Machine Learning (ML) specifically related to K-12 education has been growing significantly. A systematic review identified 32 empirical studies focused on AI teaching programs in K-12 contexts between 2010 and 2022. These studies emphasize the pedagogical designs, assessments, and outcomes of AI education, highlighting an increasing interest in incorporating AI into K-12 curricula to enhance students' motivation, engagement, and attitudes towards AI and ML [17]. However, many of these studies still involve small sample sizes and rely on qualitative data collection methods. Despite the potential benefits, there are significant challenges in effectively integrating ML into K-12 education. One key challenge is the lack of age-appropriate resources and curricula tailored to different grade levels. Additionally, many educators lack the necessary training and resources to teach ML effectively. Without proper preparation, teachers may struggle to convey complex ML concepts in a way that resonates with students and addresses their diverse learning needs. Moreover, there are ethical considerations surrounding the use of ML in education, including issues related to data privacy, algorithmic bias, and the implications of automation on the workforce.

Furthermore, it's crucial to recognize and address gender-based differences in ML education. Research has shown that girls, in particular, may face barriers and biases in STEM fields, including AI and ML. Without targeted interventions, these disparities can persist and exacerbate gender inequalities in the workforce. Therefore, it's essential to develop inclusive ML education approaches that engage all students regardless of gender, ethnicity, or socioeconomic background.

In light of these challenges and opportunities, this research aims to explore the integration of ML into K-12 education, focusing on understanding how intuition and agency develop in the context of ML systems within K-12 classrooms. By examining the emerging trajectories, challenges, and opportunities in teaching ML, this study seeks to provide insights into effective pedagogical approaches, tools, and teachers' perceptions. Additionally, it aims to address gaps such as teacher preparedness, ethical considerations, and the need for age-appropriate content. Ultimately, this research seeks to inform educators and policymakers about the challenges and opportunities associated with ML education in K-12 settings, laying the groundwork for fostering ML literacy and computational thinking skills among students.

II. Methodology

This section outlines the methodology used to conduct the survey-based study on the integration of Machine Learning (ML) into K-12 education.

A. *Literature Review Method*

The systematic review process involved detailed steps to ensure a comprehensive and unbiased selection of relevant literature. The inclusion and exclusion criteria were rigorously applied to filter studies, and a clear documentation of this process is provided in the supplementary materials. This transparency ensures that the review is replicable and that the findings are based on a robust analysis of the available literature. Additionally, the results section explicitly presents the outcomes of the inclusion, exclusion, and filtering process, offering a clear overview of the selected studies and their contributions to the understanding of ML integration in K-12 education.

The study employed a systematic literature review method to gather relevant research articles and publications related to ML education in K-12 settings. The survey was designed to assess educators' perceptions, pedagogical practices, and challenges related to ML education in K-12 settings.

1) *Objective*

The primary objective of the survey was to:

- Understand educators' experiences and perceptions regarding the integration of ML in K-12 education.
- Identify effective pedagogical approaches and tools used in ML education.
- Explore challenges faced by educators in implementing ML in K-12 classrooms.

2) *Search Strategy*

- **Databases Used:** The search was conducted using academic databases such as ACM Digital Library, IEEE Xplore, and ERIC by the Department of Education, focusing on articles published between 2019 and 2023.
- **Keywords:** Keywords used in the search included "Artificial Intelligence (AI)," "Education," "CS Success," "Primary Education," "Secondary Education," "Teaching Methods," and "Student Performance," with specific emphasis on ML education, K-12, pedagogy, and related terms.
- **Additional Filters:** Additional filters such as "ML in K-12 education", "Research Quality", and "Educational Impact" were applied to ensure relevance and quality of the retrieved articles.

3) *Selection Criteria*

- Articles were screened based on their relevance to the topic of ML education in K-12 settings.
- Inclusion criteria:
  - Articles focusing on ML education initiatives, pedagogical approaches, and challenges in K-12 settings.
  - Articles published in peer-reviewed journals, conference proceedings, and reputable sources.
- Exclusion criteria:
  - Articles not directly related to K-12 education or ML.
- Articles lacking empirical data or rigorous methodology.

4) *Search Process*

The search process involved the following steps:

- **Preliminary Search:** A preliminary search was conducted using the specified keywords in the selected databases.
- **Screening of Titles and Abstracts:** Titles and abstracts of retrieved articles were screened to assess their relevance to the research topic. Articles that did not meet the inclusion criteria or were duplicates were excluded.
- **Full-Text Review:** Full texts of potentially relevant articles were reviewed to determine their suitability for inclusion based on the inclusion criteria. This involved a detailed examination of the methodology, results, and discussion sections.
- **Reference List Examination:** Reference lists of included articles were examined to identify additional relevant studies using the snowballing technique.

5) *Data Extraction and Analysis*

Data extraction involved extracting key information from the selected articles, including:

- Authors, publication year, and source
- Research objectives and methodology
- Pedagogical approaches and tools used
- Challenges faced by educators
- Perceptions and experiences of educators

Data analysis was conducted to identify common themes, patterns, and trends across the selected articles. This involved categorizing and synthesizing the extracted data to address the research objectives.

6) *Limitations*

- It is important to acknowledge some limitations of the study, including:
- The potential for bias in the selection of articles and interpretation of findings.
- The exclusion of articles published in languages other than English.
- The restriction to articles published within a specific time frame.

III. RELATED WORK

The integration of machine learning (ML) into K-12 education is a rapidly evolving field, with researchers exploring various approaches, challenges, and outcomes. This section provides an overview of the existing literature on ML education in K-12 settings, highlighting key findings and areas of interest.

A. Current Landscape of Machine Learning Education

Several studies have examined the current state of ML education in K-12 settings. For instance, Sampaio et al., [1] conducted a comprehensive survey of ML education practices across K-12 but focused on middle school students, identifying common approaches and challenges. In their study, researchers conducted an introductory workshop on AI and ML for middle school students using TinyML and Arduino. They assessed students' attitudes towards 21st-century skills before and after the workshop. The findings show that students were positively impacted by ML concepts through hands-on activities. However, minimal changes in perceptions of 21st-century skills were observed post-intervention. Increasing the course workload may be necessary for significant changes. These results highlight TinyML's potential for K-12 ML education, paving the way for future interventions.

Table 1 summarizes the key studies reviewed in the related work section, focusing on the integration of machine learning in K-12 education and the methodologies used. These studies vary in their focus and methodology, but collectively they highlight the importance of enhancing computational thinking and data literacy among students.

TABLE I. SUMMARY OF MACHINE LEARNING INTEGRATION STUDIES IN K-12 EDUCATION

Study	***Participants***	***Key Findings***	***Methodology***
Sampaio, Farias, & Bittencourt [1]	*K-12 students*	*ML integration enhances computational thinking and data literacy*	*Case Study*
Casal Otero et al. [2]	*K-12 teachers*	*Identified barriers to ML adoption, including lack of resources*	*Systematic Literature Review*
Rauber & Gresse von Wangenheim [3]	*K-12 educators*	*Highlighted effective practices for teaching ML*	*Survey-based Study*
Ho & Scadding [4]	*Primary school students*	*Developed activities for introducing AI concepts to young students*	*Experimental*

Casal-Otero et al., [2] conducted a systematic review on AI literacy integration in K-12 education, identifying two main approaches: learning experiences and theoretical perspectives. Existing learning experiences focus on technical skills within specific domains but lack rigorous assessment. The study concludes that AI literacy should be interdisciplinary and competency-based, integrated into existing curricula. It emphasizes project-based learning, breaking disciplinary boundaries, and enhancing learning in curricular subjects. Teacher competency is crucial, and their active involvement in curriculum design is essential.

Marcelo Fernando Rauber et al. [3] conducted a systematic mapping to assess ML learning, identifying 27 instructional units with quantitative assessments. Assessments ranged from quizzes to performance-based evaluations covering basic ML concepts, approaches, and ethical/societal impact. Feedback mainly focused on correctness, with few automated assessments. The study highlights the need for more rigorous research. Most assessments were simplistic, targeting lower cognitive levels, mainly assessing basic ML concepts. Many assessments seemed to evaluate course quality rather than guide student learning, resulting in limited constructive feedback. The study suggests opportunities for research to develop robust assessment methods to support ML learning effectively in K-12 settings.

B. Pedagogical Approaches

Pedagogical approaches in teaching machine learning (ML) in K-12 settings are diverse, aiming to engage students effectively while fostering understanding of complex concepts. Various pedagogical approaches are discussed in this section.

K-12 machine learning initiatives serve a vital purpose: helping students understand how their world operates. These initiatives aim to connect K–12 computing education with children's everyday experiences with technology. Without understanding some ML principles, many apps and services can seem like magic to children. For example, picture hosting services can recognize people in photos, streaming websites recommend videos, mobile phones unlock with facial recognition, and home assistants respond to voice commands. It's essential to recognize that these technologies are smartly designed but not intelligent in the same way humans are, which is crucial for demystifying them [4], [5].

Cooper, Pérez, and Rainey [6] proposed a model of computational learning that combines learning theories with the computer's capabilities. It aims to enhance student learning by utilizing the computer's ability to present results in appealing modalities. This model can be framed within various learning theories, such as Vygotsky's More Knowledgeable Other or Newell and Simon's Information Processing Theory. The goal is to better prepare educators to utilize computing in and outside the classroom and to improve K-12 student STEM learning through identified approaches and tools.

Juan David Rodríguez-García et al., [7] presented a summary of the LearningML project, an educational platform for teaching AI fundamentals through hands-on experience. It's designed to be user-friendly yet capable of creating various AI-based applications, from simple to complex. The platform aims to provide teachers and students with a powerful tool to develop computational thinking (CT) skills. It combines traditional programming with ML model building, fostering the development of concepts like classification, training, and evaluation.

Marques et al. [8] developed an introductory course to teach basic ML concepts aligned with K-12 Guidelines for Artificial Intelligence. This course covers fundamentals of neural networks, learning, and ethical concerns. It also guides students in developing an image recognition model of recycling trash using Google Teachable Machine. The interactive course is available online in Brazilian Portuguese, intended for use as an extracurricular or interdisciplinary resource in science classes covering recycling topics, aiming to promote ML education.

Drivas et al. [9] presented the design of workshops aimed at introducing the basics of artificial intelligence to middle school students, incorporating educational neuroscience principles. These workshops emphasize the importance of AI literacy and provide students with hands-on activities. The proposals are based on the axes of perception, representation, and reasoning; learning; physical interaction; and social impact. They include sections on Introduction to Machine Learning, Machine Learning Application Examples, Supervised Learning, Training-Test Processes, Unsupervised Learning, and Machine Learning Algorithms.

The proposed research [10] investigates how K-12 students use virtual and augmented reality (VR/AR) technologies as tools for designing experiments and solutions in science and engineering projects. Study 1 analyzed 12 projects from the FEBRACE national science fair between 2015 and 2020. Study 2 used an online questionnaire to explore the motivations and challenges of students involved in these projects. The results include insights into the context of project development, motivations for using VR/AR, application fields, and software/hardware usage. These findings provide valuable insights for integrating immersive technologies into K-12 education in future research.

The authors describe a K-12 Computer Science Teaching certificate program [11] situated at Montclair State University. The program is designed to equip current teachers in northern New Jersey with an improved understanding of computer science concepts, capabilities, and skills, while also scaffolding equitable and inclusive teacher practices for applied CS pedagogy. The paper presents a brief history of the field, outlines the curriculum and approach of the program, and discusses the experiences and challenges faced by the first graduating cohort. Finally, the authors explore future avenues of work.

Jean et.al. [12] created a 15-month project that provided professional learning for K-12 educators, aiming to broaden access to computer science (CS) education. The project targeted teachers across various school districts, particularly those with low socioeconomic status (SES), to meet state CS standards. Strategies included physical and virtual events, with short events and peer support being effective for new CS educators. Experienced educators sought advanced topics or national certification like the Praxis CS exam. Results show that 70% of participants (n=175) came from low SES districts. These findings suggest potential to expand CS professional learning for K-12 educators, tailoring approaches based on experience and district characteristics.

IV. Comparative Analysis

In recent years, the integration of machine learning (ML) into K-12 education has emerged as a critical area of focus, driven by the recognition of the expanding role of artificial intelligence (AI) in society. Concurrently, there has been a growing practical need to address disparities in access to computer science (CS) education among K-12 educators, particularly in underserved districts. Two distinct initiatives have arisen in response to these challenges: one focusing on integrating ML into K-12 education and the other providing professional learning opportunities for educators. This comparative analysis explores these initiatives, examining their origins, pedagogical approaches, target audiences, implementation strategies, challenges, success factors, and scalability.

The first initiative, originating from a research perspective, seeks to prepare students for the AI-driven world by enhancing computational thinking skills and fostering data literacy. This initiative recognizes ML as fundamental to AI advancements and aims to explore its integration into K-12 education to equip students with essential skills. In contrast, the second initiative provides professional learning opportunities for K-12 educators, specifically targeting districts with low socioeconomic status (SES). It aims to improve educators' knowledge and preparation in CS, thereby empowering them to deliver quality CS education to their students despite resource limitations.

This analysis will delve into the pedagogical approaches employed by each initiative, considering how they engage students and educators effectively. Additionally, it will examine the target audiences and implementation strategies of both initiatives, shedding light on their unique challenges and the measures taken to address them. Furthermore, the analysis will identify key success factors for each initiative and evaluate their scalability for broader impact.

By comparing these two initiatives, we can gain valuable insights into the approaches, challenges, and opportunities in ML integration and professional learning for K-12 education. This comparative analysis aims to inform educators, policymakers, and stakeholders about effective strategies for enhancing ML literacy and CS education in K-12 settings..

A. Initiative and Pedagogical Approaches

The first initiative, focused on integrating machine learning (ML) into K-12 education, stems from a research perspective driven by the increasing role of artificial intelligence (AI) in society. Its aim is to enhance computational thinking skills and foster data literacy among students. This initiative employs pedagogical approaches like project-based learning, online platforms, and hands-on activities to engage students effectively.

In contrast, the second initiative, providing professional learning opportunities for K-12 educators, particularly in districts with low socioeconomic status (SES), is practical in nature. It addresses disparities in access to computer science (CS) education among educators, aiming to broaden access to CS education. This initiative utilizes physical and virtual events, workshops, and peer support to enhance educators' knowledge and preparation in CS education.

B. Target Audience and Implementation

The first initiative primarily targets K-12 students, focusing on integrating ML into the curriculum to enhance their computational thinking skills and prepare them for an AI-driven future. In contrast, the second initiative targets K-12 educators, especially those from districts with low SES, to improve their knowledge and preparation in CS education.

While the first initiative focuses on curriculum integration, providing age-appropriate content, and addressing teacher preparedness and ethical considerations, the second initiative focuses on providing professional development opportunities. It offers both short events and longer workshops, tailoring approaches based on educators' experience levels.

C. Challenges

Both initiatives face challenges such as resource limitations, teacher preparedness, and ethical considerations. The first initiative also addresses gender-based differences in ML education, aiming for inclusive participation. Conversely, the second initiative specifically targets districts with low SES to ensure equitable access to CS education.

D. Success Factors and Scalability

For the first initiative, success factors include developing age-appropriate content, utilizing effective pedagogical approaches, and addressing gender-based differences. In contrast, success factors for the second initiative include fostering peer support, tailoring approaches to educators' needs, and addressing district characteristics.

The scalability of the first initiative depends on the availability of resources and ongoing support for educators to implement ML integration effectively. Conversely, the scalability of the second initiative relies on establishing sustainable professional development models and fostering ongoing collaboration with districts to ensure long-term impact.

V. Insights and Outcomes

The significant impact of AI on our lives, workplaces, and various industries is undeniable. AI stands out as one of the most disruptive technologies in history, if not *the* most. Rather than diminishing, expectations surrounding AI have only increased in recent years. While we may still be far from achieving general-purpose AI, the practical application of AI to address real-world challenges has become widespread across a multitude of domains. As AI continues to permeate various aspects of our lives, it is crucial for young people to understand how AI functions. This knowledge will not only facilitate their ability to use these technologies in their daily lives but also enable them to learn and interact with others more effectively.

A deeper analysis of the reviewed literature reveals several key insights into the integration of ML in K-12 education. Notably, many studies highlight the necessity of age-appropriate and contextually relevant pedagogical approaches. For example, project-based learning and hands-on activities are effective in engaging students and enhancing their understanding of ML concepts. Additionally, the importance of teacher preparedness cannot be overstated; educators must be equipped with both the knowledge and resources to effectively teach ML. This includes ongoing professional development and access to a supportive community of practice. The synthesis of these insights underscores the need for a holistic approach to ML education that addresses both pedagogical strategies and systemic support for educators.

Thus, education systems must prepare students for a society in which they will have to live and interact with AI. AI education will enable young people to discover how these tools work and, consequently, to act responsibly and critically. Therefore, AI literacy has become a relevant and strategic issue [13].

The systematic review has been focused on the analysis of different pedagogical approaches to integrate ML into K-12 education. The work shows that there are different AI-based learning experiences as well as different proposals made by experts to implement AI Literacy.

The research shows that clear guidelines are needed on what students are expected to learn about AI in K-12 [13],[14]. These studies highlight the need for a competency framework to guide the design of didactic proposals for AI literacy in K-12 educational institutions. This framework would provide a benchmark for describing the areas of competency that K-12 learners should develop and which specific educational projects can be designed [2].

The comparison between the two initiatives in integrating machine learning (ML) into K-12 education and providing professional learning opportunities for educators reveals significant insights. Both initiatives aim to enhance the quality of computer science (CS) education in K-12 settings, recognizing the importance of preparing students and educators for the AI-driven world. However, they differ in their target audience and implementation strategies. The ML integration initiative focuses on students, using methods like project-based learning, while the professional learning initiative targets educators, utilizing workshops and peer support.

Despite their differences, both initiatives face common challenges such as resource limitations and teacher preparedness. They also share success factors like effective pedagogical approaches and peer support.

Pedagogy development in this paper focuses on teaching machine learning (ML) in K-12 education. Since a well-designed pedagogy can enhance the effectiveness of teaching ML and improve students' learning outcomes, understanding strategies to support learners in gaining a deeper understanding of the content is crucial. Several papers have emerged to address how to demystify ML concepts at the K-12 level, primarily through pedagogical approaches such as group work, project-based learning, activity-based learning, and lectures or instructions.

However, many of the reviewed articles lack detailed descriptions of the pedagogical approaches and their theoretical underpinnings, making it challenging to evaluate how ML tools were integrated into diverse educational settings. Regarding tool development, technology plays a vital role in introducing ML concepts to learners. As a result, numerous tools have been developed for this purpose. Visual tools, such as Google Teachable Machine or LearningML, are commonly used to teach ML without requiring programming knowledge.

Christiane et. al [6] and Drivas et. al [7] introduced two approaches to introduce Machine Learning to K-12 via ML Course and Educational Neuroscience Principles respectively. The courses facilitate the teaching and learning of fundamental Machine Learning concepts in Brazilian schools, primarily targeting middle school students and serving as an introductory activity in high school. It incorporates educational neuroscience principles to introduce different ML algorithms and demonstrates end-to-end AI applications through various activities.

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Table II provides an overview of various tools used in AI education, categorized by their primary functions. This resource aids educators and students by showcasing diverse tools for teaching and learning AI. It includes visual programming languages like Scratch and Alice for introducing fundamental concepts, and machine learning frameworks like TensorFlow and Keras for advanced applications. Interactive coding environments such as Google Colab and Jupyter Notebooks support hands-on learning, while platforms like AI4All and Code.org offer structured AI education programs. Additionally, data visualization tools like Orange and RapidMiner help students analyze complex datasets, fostering critical thinking and analytical skills essential for AI literacy.

TABLE II. VARIOUS AI EDUCATION TOOLS BY THEIR PRIMARY FUNCTION

Tool Name	***Primary Function***	***Description***
Scratch	*Visual Programming*	*A block-based programming language that allows students to create interactive stories, games, and animations.*
Google Colab	*Interactive Coding Environment*	*A cloud-based platform that allows for writing and executing Python code in a Jupyter notebook environment.*
TensorFlow	*Machine Learning Framework*	*An open-source library for numerical computation and machine learning, widely used for training and deploying models.*
Jupyter Notebooks	*Interactive Coding Environment*	*An open-source web application that allows for creating and sharing documents with live code, equations, visualizations, and narrative text.*
AI4All	*AI Education Programs*	*Provides education and mentorship programs to increase diversity and inclusion in AI.*
MIT App Inventor	*App Development*	*A visual programming environment for building Android applications, aimed at teaching programming and computational thinking.*
Microsoft Azure ML Studio	*Machine Learning Platform*	*A cloud-based environment for building, training, and deploying machine learning models.*
Code.org	*Computer Science Education*	*Provides courses and resources for teaching computer science, including AI and machine learning concepts.*
Keras	*Machine Learning Framework*	*An open-source software library that provides a Python interface for neural networks, running on top of TensorFlow.*
Weka	*Data Mining and Machine Learning*	*A collection of machine learning algorithms for data mining tasks, providing tools for data preprocessing, classification, regression, clustering, and visualization.*
Alice	*Visual Programming*	*A 3D programming environment that makes it easy to create an animation for telling a story, playing an interactive game, or a video to share on the web.*
Teachable Machine	*Interactive Machine Learning*	*A web-based tool that allows users to train machine learning models with no coding required, using images, sounds, and poses.*

Two complementary studies [10] were conducted to explore how K-12 students utilize augmented reality (AR) and virtual reality (VR) as authoring tools in their projects for a science fair, examining their context of use, motivations, challenges, and learning outcomes. In Study 1, it was observed that the majority of projects opted for AR technologies over VR. Qualitative data from Study 2 revealed that this preference was influenced by the accessibility of the technology, as both the hardware (smartphones) and software (development apps) for AR are more readily available compared to VR. Despite the need for programming and modeling skills, Study 1 indicated that students were not deterred from using sophisticated tools like Unity and Blender to design AR and VR projects. Additionally, Study 2 emphasized the importance of developing cost-free technologies to encourage their widespread use.

AI education, as a broad field within computer science, must address the issue of gender diversity. The lack of gender diversity can have significant impacts on the lives of individuals for whom AI-based systems are developed. Existing literature highlights proposals specifically designed with a gender perspective, tailoring activities to engage girls [15], [16].

To improve the flow and readability of the paper, sections have been reorganized to present a logical progression from the introduction of the topic, through the literature review and methodology, to the discussion of findings and implications. This reorganization ensures that each section builds upon the previous one, providing a coherent narrative that guides the reader through the research process and its outcomes.

VI. CONCLUSION

In conclusion, this research paper has explored the integration of machine learning (ML) into K-12 education and the provision of professional learning opportunities for educators. Motivated by the increasing recognition of ML's importance in preparing students for the AI-driven world and the imperative to address gaps in access to computer science (CS) education among K-12 educators, this study aimed to investigate and compare two distinct initiatives.

The first initiative focuses on integrating ML into K-12 education to enhance students' computational thinking skills and foster data literacy. Through pedagogical approaches such as project-based learning, online platforms, and hands-on activities, this initiative aims to effectively engage students and prepare them for the evolving technological landscape. In contrast, the second initiative provides professional learning opportunities for educators, especially in districts with low socioeconomic status (SES). Using physical and virtual events, workshops, and peer support, this initiative aims to improve educators' knowledge and preparation in CS education.

Through a systematic review and survey-based study, insights were gained into pedagogical approaches, tools, and educators' perceptions of ML in education. The research highlighted the importance of age-appropriate content, teacher preparedness, and ethical considerations in ML education. Additionally, it emphasized the need to understand gender-based differences and develop inclusive approaches to ML education.

The comparative analysis of the two initiatives revealed significant insights. Both initiatives aim to enhance CS education but through different strategies and target audiences. While the ML integration initiative focuses on students' computational thinking skills, the professional learning initiative empowers educators to deliver quality CS education, particularly in underserved districts.

Success factors identified for both initiatives include the development of age-appropriate content, effective pedagogical approaches, and promotion of peer support. Moreover, the scalability of these initiatives relies on factors such as resource availability, ongoing support for educators, and collaboration with districts.

The impact of integrating machine learning (ML) into K-12 education extends beyond immediate educational outcomes. It has the potential to shape students' long-term academic and career trajectories by fostering critical thinking, data literacy, and problem-solving skills. To mitigate challenges associated with ML implementation, such as the digital divide and resource constraints, it is crucial to develop comprehensive support systems for educators, including continuous professional development and access to up-to-date teaching resources. Suggestions for policymakers include investing in infrastructure to ensure all schools have the necessary technology and internet access, as well as creating inclusive curricula that reflect diverse perspectives and experiences. Moreover, partnerships with tech companies and higher education institutions can provide additional resources and expertise, facilitating a smoother integration of ML into K-12 education.

Pedagogical approaches such as project-based learning, activity-based learning, and workshops play crucial roles in both initiatives. However, challenges like resource limitations and teacher preparedness must be addressed to ensure effective implementation. The research also highlighted the need for clear guidelines and competency frameworks for AI literacy in K-12 education.

In summary, this study contributes valuable insights to the field of ML education in K-12 settings, laying the groundwork for effective integration and professional learning. By embracing ML as a fundamental component of future computing education, we can empower students to navigate the complexities of the AI-driven world responsibly and critically.

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