Pedagogies of Machine Learning in K-12 Context

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***Abstract*—This research Full paper presents the pedagogies of machine learning in K-12. The new learning pedagogies and technologies are introduced with the aim of enhancing student engagement, experience and learning outcome. This study examined how machine learning has been taught in the recent past and further explores the ways and suitable approaches for K-12 context. Literatures on pedagogies associated with machine learning were reviewed to understand the dynamics and suitability of these pedagogies to support machine learning teaching. Though studies have explored pedagogies for machine learning in higher education context, few studies explored pedagogical strategies for teaching machine learning in K-12. In all, the pedagogies employed in teaching and learning of machine learning has not witnessed much research in literature. The pedagogical strategies revealed in the literature are mostly adopted in the higher education institutions to enable the of teaching machine learning concepts. The literature survey revealed several pedagogical strategies such as problem-based learning, project-based learning and collaborative learning used in higher education institutions. The revealed pedagogies suggest learners-centered approaches such as active learning, inquiry-based, participatory learning, design-oriented learning among others will be suitable for teaching machine learning in K-12 settings.**

Keywords—pedagogy, machine learning, K-12, digital technologies, active learning

I. Introduction

The rise of technology within the education sector in recent times has been astounding considering the pervasiveness of its application and integration in teaching and learning process. Especially, the new age of technology, one in which artificial intelligence (AI) and machine learning are being developed. Artificial intelligence is that activity devoted to making machines intelligent, and intelligence is that quality that enables an entity to function appropriately and with foresight in its environment [1]. However, machine learning is an application of artificial intelligence that provides systems the ability to automatically learn, improve its performance on a task and without being explicitly told how to do that task [2]. Machine learning is an evolving branch of computational algorithms that are designed to emulate human intelligence by learning from the surrounding environment [3]. In recent times, many changes were observed in EdTech, such as advent of cloud technology, development of artificial instructors, virtual facilitators, interactive websites, delivery systems, online assessments and many more as a result of deployment of AI and machine learning in the educational field. According to Majumdar [4], artificial intelligence ranks among the top current trends in K-12 education tech and with its overwhelming potential in education, schools can leverage it to improve teaching and learning that transcends traditional barriers while students will be exposed to newer forms of learning.

There is a common understanding that in the current knowledge age, the 21st century learners are captivated by the application of new technological concepts such as machine learning and artificial intelligence. This study examines how machine learning has been taught in the recent past and further explores the ways and suitable approach(es) for K-12 context. Beside, this study reviews research on pedagogies associated with machine learning in K-12 settings to understand the dynamics and suitability of these pedagogies to support machine learning teaching. Though studies have explored pedagogies for machine learning in higher education context, few studies explored pedagogical tactics in K-12 [21]. In all, the pedagogies employed in teaching and learning of machine learning has not witnessed much research in literature. The objective of the study specifically is to explore pedagogies for machine learning in the literature and identifies potential pedagogical frameworks suitable for machine learning in K-12.

The study is divided into five parts. The first section introduces the topic of inquiry. The second section synthesizes applicable literature while section three explores the appropriate methodology for the study. Section four displays the result and discussion while the last section shows the conclusion with future study alertness.

II. Background

AI researchers, education technology advocates, and other stakeholders are increasingly turning their attention to education and speculating about ways that advanced AI techniques, such as machine learning, may dramatically shape the future of kindergarten through grade 12 (K–12) education, including classroom instruction, the role of the teacher, and how students learn [5][6][7]. According to Lane [8], it is important machine learning is introduced to K-12 education and classrooms to offer basic literacy to understand and appreciate how the world around them works. Pena [2] also opined that early exposure to the underlying processes of machine learning can facilitate children's understanding of the world around them and their ability to solve related problems. He further reiterates that it can prepare children for an education leadership role as well as provide them the fundamentals of innovation which allow them to practice innovation at early stage. With machine learning-assisted K-12 education, students could become even stronger advocates for their own learning. Also, with greater freedom and individualized guidance from teachers, students could explore their interests and learn to appreciate subjects they might not have been exposed to previously [9].

K–12 education system is pre-tertiary education from kindergarten through grade 12. According to [10] kindergarten is required due to the preponderance of research asserting the long-term learning and social benefits of school readiness programs; and 12 years of primary and secondary schooling due to the time needed to acquire the knowledge and skills sets necessary for 21st century university education, postsecondary training, or decent work. Silliman and Schleifer [11] study shows that the purpose of K–12 education is not only to teach academics, such as math and science, but also to prepare students for work and to be good citizens. The study further shows that K–12 education has a lot of responsibilities for ensuring workers have the skills and education they need to be successful in today's economy. Regarding what students should learn in K–12 education, in terms of career readiness, most Americans support offering more career skills classes, and most would favor having more career- or skill-based classes over having more honors classes [11]. Education researchers and other stakeholders called for more innovation in K-12 education, leveraging technology in the classroom and experimenting with different organizing models for schools, as a means to increase quality [12].

Presently, few attempts to teach machine learning for K-12 appear in literature. There is the need to prepare young people for emerging work life that is currently being greatly disrupted by ML [13]. As a relatively new field of study, teaching and learning machine learning requires appropriate pedagogic knowledge and teaching strategies couple with appropriate learning style to understand the emerging technological concept. In order to enhance active participation of children in the data-driven world, it is important to explore suitable pedagogical approaches to support machine learning in K-12 context. Since understanding the teaching and learning tactics will guide appropriately to convey knowledge of the concept.

Okojie et. al. [14], study found that there is a relationship between the use of technology and the employed pedagogies. Pedagogy was classified according to two-dimension degree of negotiation and production [15]. The authors describe negotiation as the degree of collaboration by a certain tool (e.g. working via shared document tools) and production as creating an artefact by using a certain tool (e.g. developing software by an integrated development environment). The combination of the two dimensions results in four groups, namely transmissive, dialogue, constructive and co-constructive [16]. Transmissive pedagogic classification provision of course content to a large number of students in a traditional way [17]; Dialogue oriented pedagogy focuses on the interaction and communication between students and lecturers; In a constructive pedagogy, the lecturer primarily focuses on developing a product, e.g. by creating artefacts with students as a course outcome [18] and Co-constructive pedagogy encourages lecturers to co-create such artefacts together with students conducting a series of goal-related tasks [19].

The new learning pedagogies and technologies are introduced with the aim of enhancing student engagement, experience and learning outcome. In artificial intelligence, cooperative pedagogy (also collaborative) teaching techniques include group projects, small group activities, and other activities that involve students [20].

III. Methodology

The study specifically explored the pedagogies suitable for teaching machine learning in the literatures and also identified potential pedagogical frameworks suitable for machine learning in K-12. The objectives of this study, its framework and relevant concepts have all been defined using SPICE structure as see in table I. Besides, the arrangement of this study follows the idea of SPICE [22].

TABLE I. SPICE STRUCTURE FOR THE ARTICLE

SPICE		
S	Setting	HEI and K-12
P	Population	Teachers and students across educational levels
I	Interest	Pedagogies for teaching machine learning in K-12
C	Comparison	Compare machine learning teaching strategies in different educational settings
E	Evaluation	machine learning in K-12

Design

In the quest to search for answers to the objectives raised by this study, a narrative literature review was conducted. To address the specific objectives of exploring pedagogies for teaching machine learning in the literatures, we choose narrative review, to conduct the literature review. The narrative review is the "traditional" way of reviewing the extant literature and is skewed towards a qualitative interpretation of prior knowledge [23]. Narrative review attempts to summarize or synthesize what has been written on a particular topic but does not seek generalization or cumulative knowledge from what is reviewed [24]. The primary purpose of the review is to provide a comprehensive background for understanding current knowledge and highlighting the significance of new research [25]. This study employed non-expert narrative overview approach as used by [26]. According to [80] narrative reviews can provide experts' intuitive, experiential and explicit perspectives in focused topics. Out of the different types of literature reviews, we decided to concentrate on non-expert narrative overview as it will better help us to achieve our major goal – give a broad picture of the pedagogies for K-12 in the context of Machine learning.

Search procedure

For this review, IEEE XPLORE, Science Direct, ACM Digital Library, Springer Link, and ERIC databases were searched. Selection of the databases were based on the fact that each of them is known to have sufficient amount of relevant articles related to pedagogies of teaching machine learning, which is suitable for the present study. While looking for other locations that are appropriate for finding the information we need, we considered also some scientific journals, which scope lies in the field of machine learning and education, such as International Journal of Machine Learning, Computers and Education, Computers and Human Behaviour.

Selection criteria

To effectively narrow article search to relevant research items, this study intentionally adopted specific inclusion and exclusion criteria that will reveal the pedagogies for machine learning in HEIs and K-12 education. To be considered for selection within the current study, an article needed to be concerned with pedagogies and strategies used in teaching and learning machine learning. Though machine learning is an emerging technology, we did not include information other than from journal and conference papers while we exclude information from magazines, books, book chapters and reports. Table II shows other criteria adopted for article selection.

TABLE II. ARTICLE SELECTION CRITERIA

	Inclusion	Exclusion
Publication type	Written and published in English language Available in full text Peer reviewed article	Other languages other than English Magazines, dissertations, conference papers theses, abstract, and books
Measure	Pedagogical frameworks Teaching strategies	Technological tools Learning environments Assessment strategies
Design	Literature review Mixed methodology Study cases Quantitative studies	
Population	Teachers and students involved in teaching and learning of machine learning schools	Related course such as Artificial Intelligence and Data science

Search strategy

The study selected literature based on the inclusion and exclusion criteria developed. Article search focused on machine leaning pedagogies. Specific terms and keywords were used across the different databases. The keywords used for the searching process are: Machine Learning, Pedagogies, Teaching and Learning, institutions, K-12. For the narrative overview, the literatures are presented in table III considering the authors, level of students, topic of the article and teaching and learning methods used. Altogether, 52 articles were identified from the five international databases while 37 were screened out based on inclusion and exclusion criteria in table II. Fifteen (15) articles were finally included and available for analysis.

IV. RESULT AND DISCUSSION

This section presents an overview of pedagogies used in machine learning pedagogies as seen in literatures and identified potential pedagogies suitable for K-12. The pedagogical framework creates the structure around the philosophy of teaching and learning. It is a set of guidelines relating to quality teacher practice so that all students can reach their full potential. The pedagogical framework is designed to support teachers in the delivery of high quality teaching and learning that will improve the students' ability to learn and understand the material that they are being taught.

Pedagogies for machine learning in the literature

In order to make an adequate presentation of the literature findings, we highlighted the pedagogies used in Higher Education Institutions (HEIs) and K-12 and as well describe how they were utilized in the reviewed studies. Results obtained from the studies reveals that various pedagogical tactics were reported for teaching machine learning in HEIs which are active learning, personalized learning, visualization, using real world applications, customizing to the domain(s) of students and project based learning. In K-12, problem-based learning, project based learning, design-oriented, collaborative learning, cooperative and interactive learning approached were used.

TABLE III. REVIEWED LITERATURES WITH PEDAGOGICAL FRAMEWORK FOR MACHINE LEARNING

Author	Level	Topic(s)	Teaching/learning method
Lavesson [74]	Masters students	Learning Machine Learning: A Case Study	Experimental method
Kam and Yuen [75]	Undergraduate students	Towards Research-led Teaching Curriculum Development for Machine Learning Algorithms	A module framework
Rattadilok, Roadknight and Li [76]	University students	Teaching Students About Machine Learning Through a Gamified Approach	Modified mobile game (Clash of Clans) as a teaching tool for machine learning course
Huang, and Ma [27]	First-year Undergraduate Engineering Students	Introducing Machine Learning to First-year Undergraduate Engineering Students Through an Authentic and Active Learning Labware.	An authentic and active learning tool, which consists of a public Google site repository and a course project.
Sun and Gao [77]	Undergraduate	The Construction of Undergraduate Machine Learning Course in the Artificial Intelligence Era	Proposed Application Scenarios to Drive the Teaching of machine learning
Zaghloul and Saad [78]	Not specified	A unified integrated teaching learning modular approach (UITLM) to education: application to computer engineering education and to machine learning	Integrated teaching learning modular (UITLM) approach
Lai and Chan [79]	Not specified	Machine learning class with automatic learning materials	Compilers are designed to generate required teaching materials and editable mind map graphs automatically
Chenoweth and Linos [28]	Undergraduate	Qualitative Findings from an Online Course on Machine Learning	Teamwork, personalized learning approach
Evangelista, Blesio, and Benatti [32]	High school students	Why Are We Not Teaching Machine Learni ng at High School? A Proposal	Proposed problem-based learning
Sakulkueakulsuk, et. al. [33]	Middle school students (grade 7-9)	Integrating Machine Learning, Gamification, and Social Context in STEM Education	project based learning
Sulmont, Patitsas and Cooperstock [29]	Undergraduate	Can You Teach Me to Machine Learn? An Exploration of Pedagogical Content Knowledge for Teaching Machine Learning to Non-Majors	Pedagogical tactics for teaching machine learning included visualization, using real world applicat-ions, and customiz-ing to the domain(s) of students.
Mariescu-Istodor, et.al. [35]	High school students 13 and 19 years old.	Machine Learning for High School Students.	Designed-oriented and collaborative learning
Sperling, & Lickerman [34]	High school students. Grades 10-12 (ages 16-18)	Integrating AI and machine learning in software engineering course for high school students.	The course is based on cooperative and interactive learning
Vlist, et. al. [30]	Master's program	Teaching Machine Learning to Design Students.	Embodied intelligence method to teach machine learning
Sozykin., Koshelev, Ustalov [31]	Master students	The Role of Student Projects in Teaching Machine Learning and High-Performance Computing	Project based learning

Pedagogies in HEIs

Huang and Ma [27] introduced machine learning to first-year undergraduate engineering students through an authentic and active learning labware. The paper presents pilot experiment of teaching machine learning using an authentic and active learning tool, which consists of a public Google site repository and a course project. Through the learning labware based project, students have better recognized the importance of machine learning as a data-driven approach in solving real-world problems. It changed students' perception of difficulty, and motivated students to take more academic challenges in math and data analysis. Chenoweth and Linos [28] report experiences while teaching a largely online course about machine learning at two separate universities using personalized learning approach. The study in [28] indicates that the majority of students had a strong interest in learning about machine learning regardless of their major. Students provided positive feedback regarding the format of the course and the way material was organized on Moodle. Sulmont, et.al., [29] explored the pedagogical content knowledge for teaching machine learning to non-majors undergraduate students. The pedagogical strategy for teaching machine learning that was evident included visualization (strategically choosing datasets), using real world applications, and customizing to the domain(s) of students. The study in [29] identified pedagogical content knowledge (PCK) for teaching machine learning, namely in the forms of preconceptions and barriers faced by students along with instructional strategies. Student preconceptions include ideas that machine learning is important, but also not accessible. The data from participants in the study in [29] is an evidence that it is possible to teach machine learning to those with little to no math/CS background with the approaches adopted for teaching and learning.

Vlist, et. al., [30] study aimed at creating a new teaching method to better support students in their learning of machine learning. The study targeted masters' class design students. Embodied intelligence method was employed teach machine learning. The embodiment provides the student with a tangible tool to understand and interact with a learning system. The system allows the students to quickly build a machine and thereby enables students to focus on the machine learning. Finally, [31] study on the role of student projects in teaching machine learning using master students sample shows they make used project based learning. The study in [31] shows that the students not only learn the theoretical basis but also gain experience solving real-world problems which has a positive effect on employment.

Pedagogies in K-12

Evangelista, et. al., [32] study was on a proposal about how to teach machine learning at high school. Problem based learning was proposed as an approach to teach machine learning to high school students. With the approach, through a series of problem-based activities, students are expected to understand the foundations of what does learning mean for a computer. In addition, through analogies as well as toy and real problems, the short workshop will tackle students' preconceptions, give them an insight of what tools are important for machine learning. Reference [33] focused on middle school students (grade 7-9) on integrating machine learning, gamification, and social context in STEM education. The study in [33] employed project based learning approach and based on the tactics, it was found that students had more fun, engagement, and hands-on interactivity in the workshop compared to their regular classroom.

In addition, the study of [34] describes a unique software engineering curriculum for high-school students that includes subjects in artificial intelligence and machine learning high school students from grades 10 through 12 (ages 16-18). The course is based on self-learning, collaborative learning, cooperative and interactive learning as part of the pedagogical conception that students should be active in their learning. The study succeeded in adapting academic material to the needs of high-school students. The students dealt successfully with complicated algorithms that are thought to be even difficult for undergraduate students. Students are motivated to continue research in AI and machine learning contents according to their ability. Lastly, [35] study was about designing machine learning for high school students. The results show that the students perceived the web-based tool well, and they were able to implement the system during the tutorial walk-through. The experience running the tutorial shows also that the kind of collaborative working approach suits well for high school students, and they are capable to come up with new and unexpected ideas.

Potential pedagogical frameworks suitable for machine learning in K-12

Learners do not develop competencies and skills unless they are explicitly taught by adopting effective pedagogy [36]. According to [37], the successful reinvention of educational systems worldwide depends on transforming pedagogy and redesigning learning tasks. Some pedagogical frameworks can be employed in teaching and learning machine learning as evident in table 3. There is paucity of literatures and research in teaching and learning K-12 machine learning which is obvious from the web search of scientific databases. Few articles that targeted K-12 audience in which [34][32], as shown in table 3, are proposals for students aiming at teaching the intuition between some machine learning aspects. The pedagogy revealed in the articles is mostly in the higher education institutions (HEIs) to enable teaching machine learning. Though, few of the teaching and learning strategies (problem based learning, project based learning and collaborative learning) emerge in K-12 context, we further explored pedagogical frameworks suitable for teaching machine learning in K-12 education. Hence, this will ensure that appropriate pedagogical strategies are employed in teaching K-12 machine learning.

The taxonomy of machine learning pedagogy for K-12 is depicted as a fish bone diagram in Fig. 1. The diagram looks like a fish skeleton with the head showing the classification of the pedagogy, while the pedagogies of machine learning are in the spine connected with arrows. Besides, the corresponding features of each of the pedagogical approach are represented as branches that connect to the main spine of the machine learning pedagogy. For example, the pedagogical features of participatory learning are interest driven and inquiry oriented. As shown in Fig. 1, the following are pedagogies suitable for teaching machine learning in K-12 context: participatory learning, active learning, interactive learning, design oriented, inquiry-based learning, project-based learning, problem based learning and personalized learning approach. Among the frameworks suitable for machine learning in K-12 is project-based learning. Project-based learning is an innovative approach to learning whereby students drive their own learning through inquiry, as well as work collaboratively to research and create projects that reflect their knowledge. Scientific-technological project based learning elevated pupils' motivation and self-image in all levels [38]. Hasni, et. al., [39] study on the trends in research on project-based science and technology teaching and learning at K–12 levels shows that project-based learning has positive impact on students' learning.

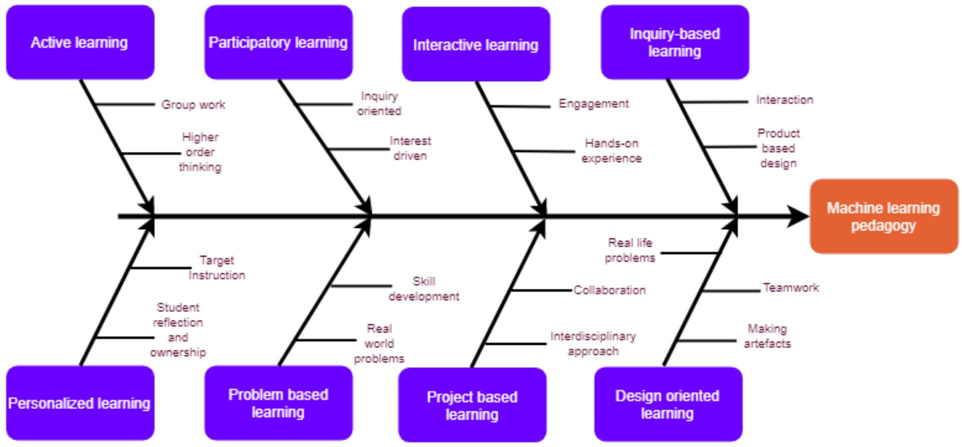

Fig. 1. Taxonomy of Machine learning pedagogy for K-12

In the study of [33] focusing on middle school students from grade 7-9 while integrating machine learning in STEM education make use of project-based learning.

The study in [33] found that students had more fun, engagement, and hands-on interactivity in the workshop compared to their regular classroom. Similarly, [35] study of high school students of 13 and 19 years old designing a machine learning method that can be understood by school students with knowledge they normally gain during their programming classes were able to implement the system during the tutorial walk-through.

Similarly, problem-based learning pedagogy was proposed by [32] for teaching high school students machine learning. Problem-based learning promotes deep understanding of subject matter content while simultaneously developing students' higher-order thinking [40]. According to [41] problem-based learning tends to include features such as learner autonomy, active learning, cooperation and collaboration, authentic activities, and reflection and transfer. Experimental evidence of problem based learning effectiveness in K–12 populations in comprehension and application of concepts in a new context after instruction showed superior mastery in problem-based learning conditions [42]. With project and problem-based learning, students learn by designing and constructing actual solutions to real-life problems [43]. Project and problem-based learning are ideal instructional models for meeting the objectives of twenty-first century education, because they employ the 4Cs Principle – critical thinking, communication, collaboration and creativity – alongside 'teaching for transfer' and learning structured in real-world contexts [44]. Several researches [45] [46] have been conducted to ascertain the effect of project-based and problem-based learning and found that learner gains in factual learning are equal to or better than gains achieved employing more traditional classroom instruction. Also, learning gains were significantly higher with project and problem-based learning than with traditional methods while a project learning approach is better matched to learners learning styles or preferences for working in groups. Studies further documented benefits of project and problem-based learning to be increased ability to define problems, improved ability to reason using clear arguments, better planning of complex projects, improvements in motivation, attitudes toward learning and work habits.

Emerging from literatures is collaborative learning as a pedagogy for learning K-12 machine learning [34]. Collaborative learning as a pedagogy has been reviewed by researchers to facilitate learning [44][47]. According to [44], learners through collaborative learning participate in higher-order thinking such as managing, organizing, critical analysis, problem resolution, and creating new knowledge. Fakomogbon, and Bolaji [47] study revealed that collaborative learning could enhance motivation, academic outcomes, and engagement through sharing knowledge. The study of [35] also shows that the kind of collaborative working approach used suits well for high school students, and they are capable to come up with new and unexpected ideas.

Active learning pedagogy can be used in teaching K-12 machine learning. This is evident in a recent study of [27] though in undergraduate settings, it shows that through the learning tactics, students have better recognized the importance of machine learning as a data-driven approach in solving real-world problems. It further changed students' perception of difficulty, and motivated students to take more academic challenges in math and data analysis. Active learning (AL) is a method for engaging students in higher-order thinking tasks (e.g., analysis, synthesis, evaluation, reflection) through various activities [48] so that students achieve more than merely the passive part of learning. Active learning is based on a theory of learning called constructivism, which emphasises the fact that learners construct or build their understanding that can then apply to new contexts and problems. Researchers from the cognitive science discipline [49][50] also suggest that classrooms with an active learning approach can increase student motivation, knowledge retention, and content transferability. Active Learning strategies can be in form of group work, presentations, group discussions, question sessions, and so on [51]. Cattaneo [52] categorizes active learning into five distinct pedagogies namely; problem-based, discovery-based, inquiry-based, project-based and case-based learning. In addition to the evidence that active learning approaches promote learning for all students, [53] shows that active learning approaches are an effective tool in making classrooms more inclusive.

In K–12 education, the impact of inquiry based learning (IBL) has been significant in elementary science education [54]. Recent research shows positive academic and achievement gains for students engaged in IBL work and the practice is growing [55]. Research has consistently shown that inquiry-based learning can be more effective than other, more expository instructional approaches as long as students are supported adequately [56]. IBL is constructivist and student-centered while it is grounded in authentic, with approach that motivates and engage students [57] [58].

Personalised learning is emerging as the way forward for global education in the changing environment of 21st century teaching and learning [59]. According to [60], rather than being composed and pre-packaged by an instructor, content is often negotiated with the learners, and requires the active direction of the student. It was further stressed that in contrast to teacher directed curricula, personal learning environments (PLE's) are learner-centric, providing relevant and timely learning opportunities by enabling individuals to select, integrate and construct knowledge using various software, services and options based on their needs and circumstance. Chenoweth and Linos [28] study reports experiences while teaching a largely online course about machine learning at two separate universities adopted personalized learning tactics. There has been study [61] that shows the effectiveness and impact of personalized learning pedagogy in K-12. As personalised learning tailors learning for each student's strengths, needs and interests, it is a potential tactics for teaching and learning machine in K-12 settings to support and ensure mastery of the highest standards possible.

Design-oriented learning that regards students as builders of knowledge is a pedagogy useful in teaching machine leaning to K-12. According to [62], Papert envisioned a world in which children design, create, and program artefacts, which can be likened to design-oriented learning. Vartiainen [63] study argues that a design-oriented learning system will enhance students' chances of becoming active agents in their own lives and learning in settings far beyond classrooms. The pedagogical approach is connected to students' interests and perceived ownership of learning [64] while it as well provides students with opportunities to generate different kinds of solutions to the problems themselves consider to be meaningful [65]. With design-oriented pedagogy, young children can participate and become active community members in the co-developed learning process and in the creation of local knowledge [66]. Using design approach, [67] study in a machine learning class shows better understanding, less confusion, more active response and better class atmosphere. Also, [35] study with design oriented tactics to design a machine learning method for K-12 and students were able to implement the system.

Another pedagogy suitable in teaching K-12 is participatory learning. According to [68], participatory learning is focused on providing opportunities and resources for learners to engage in social activities, to create a shared understanding among diverse stakeholders, and to frame and solve authentic and personally meaningful problems not delivering pre-digested information to students. It also creates environments that provide children with opportunities to explore real world phenomena in an interest driven and inquiry-oriented manner [69]. Hedges and Cullen [70] stated that participatory learning emphasizes children's active contribution in shared meaning-making and endeavours as against strict adult control or acquisition-oriented instructions. Evidence has shown the influence of the approach in K-12, such as in the study of [33]. The study in [33] presents an approach in creating activities that foster middle school students to learn the process of making machine learning with the real-world context that touches on the social issues. Based on the pedagogy used, the study found that students had more fun, engagement, and hands-on interactivity compared to their regular classroom. The finding is in support of [71] description of participatory learning as creating positive experiences that makes children have the feeling of being the author of one's actions in the world.

In K-12 settings, interactive learning approach can be employed. Interactive learning is a hands-on approach to help students become more engaged and retain more material with or without a form of technology, as it helps students strengthen problem solving and critical thinking skills [72]. Using interactive learning pedagogy, students are encouraged to control their learning and to construct meaning [74]. Interactive learning reinvigorates the classroom for both students and teachers while lectures are changed into discussions, and students and teachers become partners in the journey of knowledge acquisition [73]. Sperling and Lickerman [34] describes a unique software engineering curriculum for high school students that include subjects in artificial intelligence and machine learning. Interactive learning was proposed as part of the pedagogical conception to make students active in their learning.

The narrative overview presented some pedagogical frameworks used in teaching and learning machine learning as revealed in the reviewed literatures. The pedagogical tactics were described in the context of K-12 as well as other potential pedagogies suitable for teaching and learning K-12 education machine learning. The pedagogies description were classified on six elements representing comparative indicators identified as being emblematic of the constructivist epistemology: learner-centeredness (i.e. knowledge creation over knowledge provision); the focus on process and content; interdisciplinary lessons; collaborative lessons; a focus on student reflection; and the importance in intrinsically motivating student work as depicted by a lack of focus on assessment [52]. The potential pedagogies highlighted and described above mostly shared a common focus which is student-centred or learner-centred learning. This means that students play an active role in their learning, with the teacher as an activator of learning, rather than an instructor.

V. CONCLUSION

The aim of this study was to explore pedagogies for machine learning in the literature and identify potential pedagogical frameworks suitable for machine learning in K-12. The pedagogical tactics and strategies revealed in the literature are mostly adopted in the higher education institutions (HEIs) to enable the teaching machine learning concepts. The study described the revealed pedagogies and identified as well as described the potential pedagogical frameworks suitable for machine learning in K-12 settings. The literature survey reveals different pedagogical tactics such as problem based learning, project based learning and collaborative learning. The revealed pedagogical suggests that learners-centred approaches such as active learning, inquiry-based, participatory learning, design-oriented among others will be suitable for learning in K-12 settings. While this study is based on the review of literatures, future studies should consider a qualitative or quantitative study or mixed methodology to have a comprehensive view of the topic of inquiry. Experimentation is very important to determine or ascertain the suitable pedagogical framework for K-12 machine learning. It is noted here that the review and inference made in this study may not have provided all the underlying assumptions and experiences of the students and teachers.

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