Prospects and Limitations of Machine Learning in Computer Science Education

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Abstract

The study examined the prospects and limitations of Machine Learning (ML) in Computer Science education. Thus, it explored the concept of ML, ML algorithms, categorization, prospects and limitations of ML application in computer science education. The review indicated that machine learning offers enormous opportunities that could improve the quality of teaching and learning of Computer Science, particularly in the areas of development of intelligent tutoring systems and educational software/apps, monitoring student's learning progress and prediction of their learning styles and outcomes, automated assessment and grading, customized lecture, student placement decision, teachers' training, sentiment analysis, academic translations, detection and diagnostic supports for at-risk students. Also, it highlights several machine learning algorithms like; K-Nearest Neighbour (KNN), Naïve Bayes, Neural Network, Random Forest, Decision tree and many others that have prognostic capabilities that are of great interest to educators and are being used to advance teaching excellence and assist students and educators to access online education resources and improve their experiences. Thus, it concluded that machine learning is a promising pedagogical technology that can change the narratives in the education sector in no distant future both in terms of content development and delivery, mode of instruction, learning, feedback and evaluation pattern.

Keywords: Machine Learning, ML Algorithm, Intelligent system, Academic prediction, Artificial intelligence, Computer science education.

Introduction

The evolution of Artificial Intelligence (AI) and its successful deployment in different areas of human endevours have shown that machines have the ability to perform some human-related tasks including some activities that involves high cognitions. The success stories associated with the deployment of AI has increased the motivation of scientists to seek new ways or models to manage data, improve the accuracy of decisions on data, and to improve the quality and access to education globally. Machine Learning (ML) is one of the emerging technologies from the artificial intelligence family that are being integrated into the teaching and learning process (Onyema, 2019). Machine learning is a technique that allows machines to mimic humans both in terms of reasoning and behaviour (Krish, 2013). The ML technology is taking the performance of AI systems to the next level due to its features and capabilities. Machine learning present models that can be trained with data, and then it becomes autonomous over time to understand the patterns of the data, and is also able to make decisions on the data to solve a given problems with speed.

Knowledge of machine learning enhance the creation and application of quality, economical and smart educational materials (Michael Gr. & Abdel-Badeeh, 2020). ML has increased the academic and scientific debates on the prospective role of Artificial Intelligence (AI) on human education. Machine learning and other related emerging technologies has the potential to play a key role in redefining the teaching profession particularly as it relates to the role of a teacher, the content to be taught; the method of teaching; and the mode of student evaluation. Machine learning algorithms such as K-Nearest Neighbour (KNN), Naïve Bayes, Random Forest, Decision tree and many others have prognostic capabilities that are of great interest to educators. For instance, the learning patterns of students and their performances can be predicted using ML algorithms. By determining the learning style of students using machine learning, teachers can easily understand the individual learning differences of their students and then adopt appropriate measures to diagnose student's learning difficulties (Elhaj et al., 2020). In this era of big data, machine learning skills equip students and educators with contemporary knowledge to compete in modern world (Vijaya & Priya, 2018; Onyema et al., 2020). Educational curriculums have to be flexible enough to accommodate the teaching and learning of emerging technologies such as ML in line with 21st century trends in education (Onyema et al., 2022). This would not only afford students the opportunity to acquire knowledge of recent technologies, but also challenge the teachers to update their professional knowledge and skills on emerging technologies and current topics relating to their fields. The inclusion of machine learning in the school curriculum at the secondary or tertiary level of education are key to the achievement of modern educational goals that encourages the teaching and learning of modern skills to prepare the learners for the future.

Computer Science education provides foundations for students to learn digital literacy skills including recent developments in computing world. Topics in Computer Science evolve over time due to the constant changes in the world of computing which demands continuous review in the course curriculum in line with the emerging trends in computer education. The teaching of Computer Science or ICT cut across all levels of education. Even law students are required to take "Introduction to Computer Science" as

part of the mandatory requirements for completion of first degree programme in Nigeria. The reason for the inclusion of Computer science as a General Study (GNS) course for most programmes at the undergraduate level in Nigeria is not farfetched because of the growing influence of computer technology across all disciplines, which now requires all professionals to posses at least basic knowledge of computer or digital literacy skills in order to fit into the digital world of works.

Computer science education is not only designed to aid learners' understanding of hardware and software but also to enhance their abilities to manage, analyze, and secure data, systems and applications. Therefore, effective teaching of Computer Science could help educators and students to keep pace with emerging technologies and other events in the computing world. The understanding of machine learning and other associated technologies is crucial for effective teaching and learning of Computer education of the present and future generation of learners, who are faced with emerging digital realities that obviously requires them to be well equipped with contemporary knowledge and skills to increase their chances of employment. The present study reviewed the prospects of machine learning on Computer Science education, with a view to assist Computer science students and educators to understand the pedagogical potentials of machine learning, and how it can be applied to improve the quality of teaching and learning of Computer Science at all levels of education. This paper was discussed under the following subheadings

- Concept of Machine Learning
- Categorization of Machine Learning
- Prospects of Machine Learning in Computer Science Education
- Limitations of Machine Learning
- Artificial Intelligence and Computer Science Education
- Conclusion and Recommendations

Concept of Machine Learning

Machine Learning is part of Computer sciences that evolved from the study of pattern recognition and computational learning theory in artificial intelligence (Britanian.com, 2020). According to Arthur Samuel cited in Phil (2013), machine learning occurred when computers are exposed to training and learning to enhance their abilities to learn and act with or without much supervision. Machine learning is an automated detection of meaningful patterns in data, and one of the fastest growing areas of Computer Science, with far-reaching applications (Shai & Shai, 2014). Machine learning is a technique that allows systems to acquire, and integrate knowledge through large-scale observations, and to improve, and extend itself by learning new knowledge rather than by being programmed with that knowledge (Beverly, 2009). The workability of machine learning depends on its ability to understand different features or attributes of a training datasets or test data which enables it to predict future behaviours or imitate human brains. According to Krish (2013), machine learning is based on a set of algorithms that can process a wide variety of data that normally is difficult to process by hand. These algorithms include Decision tree learning, Neural networks, Naive Bayes, clustering algorithm, K-Nearest Neigbour (KNN), Genetic algorithm, learning algorithms,

explanation-based learning, instance-based learning, Reinforcement-based learning, Support vector machines, Associative rules, Recommender algorithms (Krish, 2013).

Machine Learning is a promising technology that can change the narratives in the educational sector in no distant future both in terms of content, methodology, and evaluation pattern. In machine learning, machines (computers) are programmed to learn, retain and act independently to solve problems with little or no human interference by manipulating data that has been provided to the model. Machine learning algorithms learn from data rather than through explicit programming, and as the algorithms ingest training data, it is then possible to produce more precise models based on that data (Judith & Daniel, 2018). The machine learning algorithm update answers to problems as modifications are made to the model. Some machine learning models are *online* and continuously adapt as new data is ingested while the other models, called *offline machine learning models,* are derived from machine learning algorithms but, once deployed, do not change (Judith & Daniel, 2018). The digitalization of images, videos, voice and text has created an environment where machine learning can thrive, and this has allowed AI researchers to revisit old artificial neural network models, training them with very large datasets (Tuomi, 2018).

There is an emerging appetite for machine learning approaches as a result of the emergence of Big Data, and a shift towards more complex instructional domains (Cristina et al., 2018). The evolution of machine learning has increased the ability of machines to understand and manipulate complex data and then make decisions on it, but it is still black boxes for many scholars because of its novelty (Himabindu et al., 2015). Kucak et al. (2018) opined that Machine learning application in education, would enhance digital learning in the nearest future. For Ibtehal (2018) the use of Machine Learning and educational technology enabled teachers to monitor the learning progress of their students and to help special students overcome learning difficulties. Fedor & Anders (2018) developed a machine learning algorithm with capabilities to detect students' prior knowledge of a subject based on symbolic regression, and averred that ML was an effective algorithm in determining students' performances. The use of K-NN algorithm is effective in evaluation of students' learning styles and had the potential to improve teachers' ability to understand individual student's learning pattern and future performances (Elhaj et al., 2020).

According to Steven and Gail (2011) machine learning is an important educational tool which ease the understanding of concepts by high school students. Therefore, a platform to enhance the awareness of machine learning technology among schools was developed by them. Xiaojin (2015) stated that machine learning techniques could be deployed to improve the quality of training and practicality in education. Trained models can be used to simulate behaviours and ensure minimal errors by trainees. Himabindu et al. (2015) examined machine learning framework to identify vulnerable students in classes. They made use of classification algorithms in line with performance metrics to monitor performances, and assist students with learning difficulties. Tuomi (2018) assessed different applications of AI in the education sector, particularly in the classroom. He concluded that AI supports modern teaching and learning techniques, but it requires proper training of staff to integrate them in the classroom. Popenici & Kerr (2017), on the impact of AI in teaching and learning in higher education. Opined that many tasks in education were being replaced by AI-machine learning techniques, and that

higher education institutions should embrace the vast opportunities offered by AI to enrich the quality of teaching and learning.

Machine learning can be applied in different areas, including pattern recognition-voice and facial recognition, biometrics, Sports prediction, driverless vehicles, Filtering system, categorization of DNA, Games, Customer service, Forecasting, searching, Ranking and recommending and prototyping. The predictive ability of machine learning algorithms is helping many companies and organizations to predict customers' or users' behaviours based on their activities on the platform. For instance, big players in the technology industry such as Amazon, Google, Apple, Facebook, Twitter, and Netflix are using machine learning algorithms to improve user experiences by speeding and matching up their search. With the aid of machine learning capabilities, the personality of a user can be accurately predicted based on his or her information available on the database and the previous activities on the account or page. Machine learning are being deployed on social networks to enhance user experiences, including the ability to relate images, relationships and locations. Posts can easily be tracked and filtered for possible community abuse. Judith & Daniel (2018) states that machine learning technology is embedded in applications throughout enterprises in order to improve performance, increase customer satisfaction, reduce customer churn, and boost revenue. Machine Learning enhances the understanding of data and the identification of patterns of data which can assist institutions and organizations to improve the quality of their products and customer relations.

The prediction of users' action provides guide for vendors to recommend products and services to potential customers exposing them to wide range of options and beguiling them to buy more. Vishal & Sonawane (2016) stated that machine learning techniques like; the Naive Bayes (NB), Maximum Entropy (ME), and Support Vector Machines (SVMs) have achieved great success in sentiment analysis. There is an increasing number of educational institutions that are fast embracing machine learning techniques to improve their efficiencies and speed (Ibtehal, 2018). One of the benefits of incorporating machine learning techniques in education is the automation aspect of enriching the knowledge base with self-learning techniques with minimal human intervention in the process (Krish, 2013).

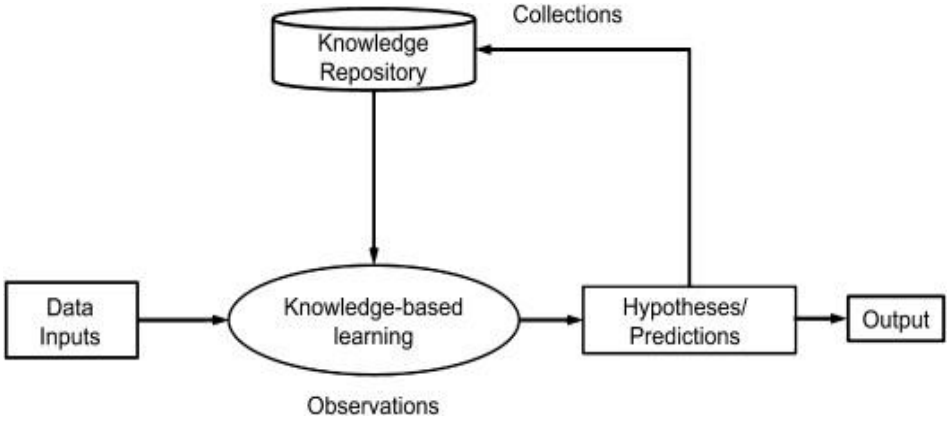

Figure 1: Machine Learning Process (Krish, 2013).

Consequently, Judith and Daniel (2018), categorized the training of a machine learning algorithm to create an accurate model into three steps:

Representation: The algorithm creates a model to transform the inputted data into the desired results. As the learning algorithm is exposed to more data, it will begin to learn the relationship between the raw data and which data points are strong predictors for the desired outcome (Judith & Daniel, 2018; Elhaj et al., 2020).

Evaluation: As the algorithm creates multiple models, either a human or the algorithm will need to evaluate and score the models based on which model produces the most accurate predictions. It is important to remember that after the model is operationalized, it will be exposed to unknown data. As a result, make sure the model is generalized and not overfit to your training data.

Optimization: After the algorithm creates and scores multiple models, select the best performing algorithm. As you expose the algorithm to more diverse sets of input data, select the most generalized model (Judith & Daniel, 2018).

Categorization of Machine Learning

The categorization of Machine learning technique is based on the type of datasets. Tutorialspoint (2019) categorized machine learning into supervised learning; unsupervised learning; reinforcement learning; deep learning; and deep reinforcement learning as shown in figure 2.

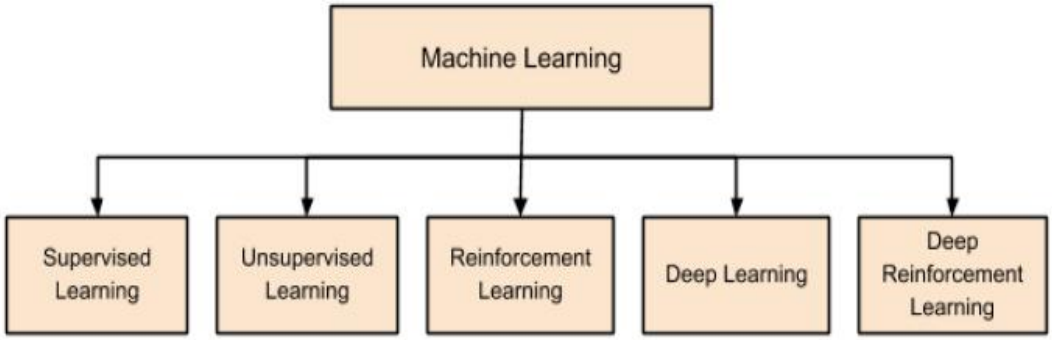

Figure 2: Categorization of Machine Learning (Tutorialspoint, 2019).

Supervised learning takes place if the model is fed with data that has labels while the Unsupervised learning deals with unlabeled data. Both supervised and unsupervised learning have their pros and cons depending on the use of the model.

Supervised Learning

Supervised learning uses historical data to predict future actions or events. This means that its function relies heavily on the past without much consideration of likely changes or innovations which can alter events. The supervised learning algorithms use a known dataset (called the training dataset) to make predictions. Some of the algorithms

for supervised learning include: Naives Bayes, K-Nearest Neigbour Algorithm, Support Vector machines, Decision trees and Logistic regression.

Unsupervised Learning

Unsupervised Learning also known as self-organizing maps is a type of machine learning that are used to group cases based on similar attributes, or naturally occurring trends, patterns, or relationships in the data (Colleen, 2015). The unsupervised learning algorithms are type of machine learning algorithms used for inferences from datasets consisting of input data without labeled responses (Elhaj et al., 2020), and it is based on rewards and punishments. Unsupervised learning aims at extracting regularities from datasets, in order to simplify their description by reducing them to their most characteristic elements (Lesot, 2006). It can be applied in facial recognition technologies and others.

Reinforcement Learning

Reinforcement learning is an aspect of machine learning that deals with how software agents ought to take actions in an environment in order to maximize the notion of cumulative reward (Wikipedia, 2020). Reinforcement learning deals with the ability of learning the associations between stimuli, actions, and the occurrence of pleasant events, called rewards, or unpleasant events called punishments (Stefano & Mathias, 2013). It is a type of machine learning technique that enables an agent to learn in an interactive environment by trial and error using feedback from its own actions and experiences (Kdnuggets.com, 2018). It can be applied to different areas, including Operation Research due to its generality and usefulness.

Deep Learning

This is a kind of machine learning that enhances the understanding and interpretation of data, features and knowledge. It involves the imitation of human brain, giving the model the ability to think and act like humans. Deep learning technique is used for extracting high-level abstract features, providing improved performance over the traditional models, increasing interpretability and also for understanding and processing of biological data (Navamani, 2019). Deep learning models such as Deep Neural Networks (DNN) and Convolution Neural Networks (CNN) are being used for categorizing reactions, cross-lingual problems as well as product review analysis (Koyel et al., 2019).

Prospects of Machine Learning in Computer Science Education

The rapid technological development of the last decades created new complex problems and changes in the education sector, the solution of which requires not only critical thinking, but also another mode of advanced thinking that has been called Computational Thinking (Michael Gr. & Abdel-Badeeh, 2020). The educational system in the 21st century has gone beyond the wall of classrooms or the positioning of teachers as masters of knowledge. The contemporary teaching and learning process requires current knowledge and use of modern technologies to achieve the set objectives. Machine learning is among the recent technologies that is transforming the educational sector. It is an aspect of Artificial Intelligence (AI) that embeds human reasoning and behaviour to

machines, giving them the ability to perform human related tasks autonomously based on pattern threads of activities or data inputted into the machine.

Ibtehal (2018) opined that machine learning is a subset of Artificial Intelligence that enable computers or teaching devices to learn from all previous data and make intelligent decisions. Xiaojin (2015) states that machine teaching can be used to design optimal lesson for individual students and to maximally influence the learner via optimal training data. Machine Learning can help educational institutions to test the workability of a strategy, before adopting it. Gordon (2019) stated that machine learning is optimizing and personalizing learning experiences for students and helping teachers. Machine learning can potentially foster quality learning and redefine how education is delivered (Pallavi & Bramah, 2019).

The growing shortage of qualified teachers coupled with growing numbers of students world-wide, represents a substantial societal global challenge and provides a strong motivation to continue to invest in solutions to enhance and support human learning and development (Cristina et al., 2018). Machine Learning offers some help to educators on learners' mental and cognitive ability. Machine learning can also act as a virtual assistant - providing automatic and real-time responses to queries by users on interactive forums or tutorial platforms. Machine learning enhances the efficiencies of educators by enabling them to complete multiple tasks such as classroom management and scheduling at ease (thetechedvocate.org, 2019). The adoption of Machine learning enhanced the development of free, user-friendly software and other educational content that is easily understandable to general audience and available over the internet (Vijaya & Priya, 2018). Machine learning based assessment provides constant feedback to teachers, students and parents about how the student learns, the support they need and the progress they are making towards their learning goals (Kucak et al., 2018).

Machine learning presents a lot of opportunities and challenges to computer scientists on how to find answers to numerous questions using mathematical equations and programming codes. Other prospects of machine learning in education are summarized as follows:

***Mitigating Examination Malpractices*:** The ability of machine learning algorithms to accurately assess students present futuristic solutions to errors and malpractices associated with human involvement in students' assessment or grading. The ability of machine learning to recognize speeches and handwriting can also be useful in checkmating academic frauds.

Improved Students Performance: Prediction of students learning styles or performance provides teachers with opportunity to put interventions in place to prevent students' failure. By identifying "at risk" students and weaknesses early, schools can detect and contact those students and help them to be more successful (Kucak et al., 2018).

Academic Translation: Educational books can easily be translated into different languages with the aid of machine learning algorithms. Machine learning models can also be applied in testing the reliability and validity of educational software.

Teacher Support: Machine learning techniques could be used to perform routine tasks like class attendance and customized lectures, thereby reducing the workloads of the teacher. ML can also improve teaching by repeatedly observing how students react and generalize rules about the domain or student (Beverly, 2009), thereby assisting the teacher to generate feedbacks and improve their quality of teachings.

***Plagiarism Detection*:** Machine learning techniques are been used to develop plagiarism software which are often used to improve the quality of papers for publication and to enhance academic integrity.

***Promotion of Learning Interests*:** Through recommendations and filtering systems, machine learning solutions often motivate learners to increase their reading skills or develop interests in a given topic being recommended.

***School Finance*:** The use of machine learning solutions enhances security of financial records or transactions of educational institutions. Machine learning algorithms are useful in detection of credit card frauds in schools. Similarly, the wave of interest and investments in artificial intelligence could also improve the revenue of educational institutions, particularly those who are involved in provision of AI products or solutions (Popenici & Kerr, 2017). The use of machine learning solutions could reduce cost for educational institutions in the future.

Research: Machine learning has many features that could enhance practicality in education and research. For instance, researchers often use machine learning technique to carry out detection, perception and sentiment analysis which are very vital in data mining and prediction of research outcomes.

***Security*:** The implementation of machine learning in education has brought about the production of AI-driven trackers which can be attached to school buses or school hostels to support campus security (medium.com, 2020). There are also emerging robots which are being used for campus security and anti-spam software that help filter academic e-mails. ML is also useful in school biometric designs for staff and students.

***Career or School Choices*:** The use of machine learning prediction model could help educational institutions in making subject placement decisions for students based on their activities or attributes. Students can also objectively analyze their skills, abilities, and interests, and based on them, pick the right schools or path after graduation (medium.com, 2020).

Automated Grading System: The development of automated paper grading systems is being made possible through the use of machine learning algorithms. Machine learning is helping teachers to grade quicker and with a greater accuracy (Gordon, 2019), thereby reducing bias and human interferences, and also quickening result computation.

Intelligent Tutoring System: The use of machine learning brings about adaptive automated tutoring systems that are capable of engaging students in real-time discussions, and provision of feedbacks to learners (Pallavi & Bramah, 2019). ML techniques are used in tutoring systems to acquire new knowledge about students, identify their skills, and learn new teaching approaches (Beverly, 2009). Intelligent online systems are programmed in such a way that it accepts learners' questions, analyze it and provide quick answers or feedbacks to the learner (Onyema et al., 2022).

Access to Online Educational resources: With the aid of machine learning algorithms, students and educators can easily access educational materials online. For instance, the search engines are able to predict and recommend useful educational materials to the users based on their previous searches. Also, in intelligent educational systems Machine learning (ontologies) are used to help the search of learning materials and pedagogical resources in the internet or as a chain playing the role of a "vocabulary" among heterogeneous educational systems that have been programmed to communicate to each other-multi-agent systems (Michael Gr. & Abdel-Badeeh, 2020; Cakula & Salem, 2011; Tankelevcience & Damasevicius, 2009).

Academic Advising and Counseling: The ability of machine learning technique to observe and predict students' behavior or learning patterns makes it a vital tool for academic counseling and advising. Teachers can leverage on the potentials of ML techniques to obtain diagnostic data to assist students deal with learning difficulties or to regain their confidence.

Limitations of Machine Learning

Nearly all technologies have their limitations and machine learning is not an exception. A computer program is said to learn from experience (E) with respect to some class of tasks (T) and performance measure (P), if its performance at tasks in T, as measured by P, improves with experience (Tom, 1997). Consequently, the accuracy of outputs or decisions expected from machine learning technique largely depends on the quality of experience and input in the machines. Machine learning techniques are prone to machine mistakes. Errors can emanate from data mining process, subjectivity, classification, or interpretations etceteras. Machine learning is also new and might have some flaws that could mar its precision and accuracy, particularly as it relates to educational grading systems. Popenici and Kerr (2017) warned that education is eminently a human-centric endeavor, not a technology centric solution, thus, the idea that we can solely rely on AI or any other technologies is a dangerous path. While machine learning brings great promise for the future of education, relying on it totally would be a big mistake (givingcompass.org, 2020). The application of machine learning in the teaching and learning process can take away personal interactions from the students which could negatively impact their ability to make friends and present themselves well in the workplace over the years ahead. (Thetechedvocate, 2018).

There is skepticism about security of data, missing data, inaccuracies in predictions, over fitting of small data, and the fears over possible replacement and displacement of workers by machines in the nearest future. If machines can work independently and effectively including as a tutor, many employees across different

professions particularly those in the academic world may likely be displaced from their jobs. A number of researchers have developed machine learning algorithms to assist educators but the challenge is improving the accuracy, sensitivity, and specificity of the machine learning algorithms (Fedor & Anders, 2018). Machine learning algorithms are prone to different errors including classifications errors which can affect its output and acceptability. Similarly, Popenici and Kerr (2017) highlighted the need for educational institutions to be mindful of the use of Machine learning /AI solutions to avoid privacy breaches by those who control the algorithms. Machine learning technique can help streamline and improve the teaching and learning process, but they cannot replace the cultural element of learning, which can only come from another human (givingcompass.org, 2020).

Artificial Intelligence and Computer Science Education

Artificial Intelligence is the branch of Computer Science that focuses on the theory and practice of creating "clever" machines that mimic the human intelligence and behavior, i.e., been able to think, hear, talk, walk and even feel (Michael Gr. & Abdel-Badeeh, 2020; Mitchell, 2019; Kastranis, 2019). Artificial intelligence is computing systems that are able to engage in human-like processes such as learning, adapting, synthesizing, self-correction and use of data for complex processing tasks (Popenici & Kerr, 2017). AI has the ability to perform tasks commonly associated with intelligent beings. However, deep expertise in AI technology is scarce, and many educators and policymakers now struggle to get up to date with basic knowledge in this area (Tuomi, 2018). AI performs human-related functions including cognitive-based activities.

Artificial Intelligence (AI) systems have attracted a lot of interests in the academic world. AI solutions open a new horizon of possibilities for teaching and learning Computer science in higher education (Popenici & Kerr, 2017). Different AI-aided systems and devices are increasingly being adopted by many educational institutions to facilitate efficiencies, transparency, and to create solutions to problems in the educational sector. AI is helping students and educators to improve their experiences and understanding of concepts. Students are able to relate better using intelligent tutoring system and applications with their teachers and peers. Course contents are better represented using different forms for easy understanding by learners by the aid of intelligent. Also, AI systems often increase the interactivity of students with their teachers, students can easily receive feedbacks on questions. The application of AI in education has reduced academic fraud and bias in student assessment and evaluation. Human intervention in testing and scoring could be reduced to a large extent using intelligent systems. Using AI system enhances student's placement decisions; thus, students can easily be categorized based on their scores or performances and then placed into corresponding subject streams accordingly. AI also has the potential to enhance management of Computer education data, particularly in this digital era of Big Data.

Conclusion and Recommendations

The significant pedagogical potentials of machine learning technology can be tapped to improve the standard or quality of teaching and learning, particularly as it relates to problem and practical-based Computer Science education. This therefore call for the need to observe caution during its implementation in Computer Science education

to avoid overhyping the technology, and to appreciate the human and cultural elements in education.

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