International Journal of Difference Equations (IJDE).
ISSN 0973-6069 Volume 17, Number 2 (2022), pp. 165-176

https://www.ripublication.com/ijde.htm

Machine Learning and Stem Education: Challenges And Possibilities

Kehdinga George Fomunyam

Durban University of Technology.

Abstract

Science, technology, engineering, and mathematics (STEM) fields are important in national and international economies in driving innovation and improving the economy and workforce pattern to meet 21st century realities. For this goal to be achieved, there is a need for innovation that will drive the economy of the future, which can only be acquired from advances in science and technology. The major rationale behind STEM education is to foster critical thinking skills, which would result in our having more creative problem-solvers in the workforce. The world is gravitating towards a knowledge-based economy, therefore having creative problem-solvers will provide answers to the complex problems of the future. This paper relied on literature review to critically address the topic under consideration. A theoretical analysis of STEM education and machine learning was conducted to clarify the nexus between the two. The key point of this study is the impact of machine learning on STEM education, as properly enacted. Findings from this research revealed that, with the current changes manifested in the global sphere, generally, it is important to leverage STEM education. With more focus on some emerging technologies. such as artificial intelligence and machine learning, the multi-versatility of machine learning has been brought to fore in many areas of computing. This includes spam filtering, and optical character recognition. There are thus ample benefits of STEM education, in that it increases innovation and creativity. STEM reduces the time and stress associated with the rigours of teaching, by providing a better standardization system. STEM education also minimises the stress associated with scoring students, predicting future behaviour and performance of students, and changing the old methods of education. The study recommended that adequate support be provided to stakeholders in the educational value chain, such as teachers, students, policymakers, etc. to familiarise themselves more with machine learning as a concept and a practice. Capacity-building workshops should also be provided for these stakeholders to ensure that they are properly oriented to adopt machine-learning approaches in their classrooms, with minimal rigour and stress.

Keywords: STEM, STEM Education, Machine Learning.

Introduction

The versatility of technology is without question these days. Technology is everywhere, including the educational sector, where it is pivotal to ensuring desired learning outcomes for students. This is in line with the findings of Jonassen (2000, 2005), who maintained that technology is important in providing support to creativity and problem-solving. Education, over time, has had a facelift; and its conduct has changed. It has moved from the old paper-based method in which texts are reeled out to students without clear and standardized metrics for understanding the overall input and output of the entire learning process. Technology has helped in advancing the frontiers of STEM education, by ensuring that the curriculum meets up with current realities, making learning more effective and resourceful. The development of any country is dependent on a strong educational programme that guides students to develop innovative capacities in STEM disciplines, vital in preparing students for better careers in the future. At the heart of technology in education is artificial intelligence. This is a broad category embedding other technologies within it. Machine learning, as a major part of artificial intelligence, has been a significant part of technology for education, facilitating human interaction and learning. Machine learning is versatile, in that it is used for a variety of functions. According to Tomei (2013), machine learning is an innovative tool used in providing solutions for cancer, climate change, and terrorism. This highlights the versatility of machine learning in solving multiple problems.

The application of machine learning to STEM education is significant in that it can be used to review a lesson that seems difficult to understand (Lv *et al.*, 2015). STEM disciplines, which are sciences, technology, engineering, and mathematics, are often seen as difficult by students. There is a need to have a better approach to these subjects that will make it simple, fascinating, and comprehensible, so that learning goals can be achieved. Multiple options must therefore be provided which can help the learner discover the best learning approach. Machine learning sees each student as different; and this variation is considered by seeking bespoke solutions to the individual learning needs of students. This typifies the propensity of machine learning to synergise with students, understanding their learning needs, and finding solutions to them. Machine learning also offers virtual assistance to students (Lv *et al.*, 2015) per communication. This works using communication agents linked to an application or a website which helps students with their needs. Consequently, machine learning has proved important in STEM education, contributing to learning along STEM lines. This study will provide evidence of the importance of machine learning in STEM education, the challenges of STEM education, and how machine learning can be applied to overcome such challenges.

STEM Education

Although history has been a major factor in shaping STEM education, there are many opinions on the origin of STEM education and its definition. Various authors and bodies have offered their own perspective on what STEM education entails, and this will be considered. STEM education originated from the works of the National Science Foundation which is affiliated to the government of the United States. According to Sanders (2009), STEM was initiated as SMET, which is an acronym for science, mathematics, engineering and technology. The major motive behind STEM education was to engender and foster critical thinking skills, which would result in having more creative problem-solvers in the workforce (White, 2014). The world is gravitating towards a knowledge-based economy, which requires such creative problem-solvers. The concept of STEM education is different from the conventional educational system. being predicated on integration. This integration is conducted in order to foster and develop the analytical and other skills needed for student learning (Maslen, 2007). When this is encouraged, it will result in the country having graduates that are marketable in the workforce. Such employees will be able to provide solutions to challenges of the nation, while competing with others in the international sphere. President Barack Obama brought STEM education into the limelight, in the drive to keep America at the forefront of innovation. Obama opined:

> "America will not succeed in the 21st century unless we do a far better job of educating our sons and daughters. And the race starts today. I am issuing a challenge to our nation's governors and school boards, principals and teachers, businesses and non-profits, parents and students: if you set and enforce rigorous and challenging standards and assessments; if you put outstanding teachers at the front of the classroom; if you turn around failing schools – your state can win a Race to the Top grant that will not only help students out compete workers around the world, but let them fulfil their God-given potential. (Office of the Press Secretary, 2009, p.2)."

STEM was conceptualized by the partnership for 21st century skills as an inquiry-based system that synergizes teamwork and instruction in the soft skills necessary for business and industry. This definition sees STEM education through the lens of collaboration and pedagogy to build the skills that are needed for optimal production in the marketplace. Graduates must not only be proficient academically; they must possess apposite skills vital to the success of any enterprise. The conducting of businesses has changed globally, and the bulk of it is technologically infused. There is therefore the need to upskill so as to fit into this new paradigm. Morrison and Bartlett (2009) highlighted that STEM integrates both curriculum and instruction, removing the chasm between subjects. This is in line with the integrative properties of STEM education in combining various disciplines into one. This opinion is supported by the views of Holley (2009), who maintained that STEM education is a multidisciplinary tool for surmounting the divisional approach to education. STEM education also has at its heart creativity, which is a precursor to innovation (Ogunleye & Tankeh, 2006: Tankeh & Ogunleye, 2006). When creative abilities are encouraged in people by subjecting them to more knowledge of STEM subjects, new means and methods for addressing issues become prominent. This is in line with the views of Ramirez (2013), who maintained that creativity and innovation in STEM education develops understanding of issues from various novel and creative dimensions. With new changes coming each day, it is necessary to address such with contemporary solutions. This can be encouraged by creativity and innovation, which is the major ideal of STEM education.

Intensified efforts have been made to ensure that all stakeholders necessary to developmental issues, especially in education, such as policymakers, school administrators, academics, inter alia, encourage and promote creativity in conducting STEM education, as revealed in the works of Kelton & Saraniero (2018); Oner, *et al.* (2016); Kim & Chae (2016); Henriksen (2014; 2017); Kang & Kim (2013); Kim, *et al*. (2012); and Tarnoff (2010). With intensified efforts towards creativity and innovation, the many challenges bedevilling the world will be solved by means of STEM education. With the many and varied and changes taking place globally, such as international economic downturns, environmental issues, regional peace, unemployment inter alia, there is a need for a system of education that will factor in these changes into the curriculum. Changes must be critically addressed, solving them by using the tools of creativity and innovation which STEM education promises. STEM is a method of teaching and learning that is predicated on problem/project, collaborative work, and is geared towards finding solutions to real-life challenges.

The increased demand for STEM education can be seen as an answer to the downward spiral in workforce patterns and economic indicators. Williams (1996) opined that there is promotion of technology education in situations of economic meltdown, taking Australia as an example. In that country, there is a positive correlation between economic depression and developments in technology education of the 1890s, 1930s, and 1980s. This implies that, as a panacea for economic depression, technology education has been strengthened and intensified to overcome the challenges concomitant with the economic downturn. With modern technologies, there will be a shift in workforce patterns and production processes, which will yield dividends. The economic crisis of 2007-2009 was seen as a clarion call to STEM education, globally.

Also, as a result of vocational and economic goals, there has been renewed interest in STEM education. According to the Central Office of Information (2008), STEM education helps in realising an exciting future, exposing people to a broad range of interesting and positive career opportunities. STEM education can help in overcoming the shortage of necessary skills in science and engineering disciplines. STEM strategies also serve in developing a strong base of scientists, engineers, technologists, and mathematicians (Department for Education and Skills, 2006). According to Chounta (2019), in the US, there is a great demand for people with STEM backgrounds. Having a STEM-educated workforce will mitigate the many ills that have befallen the populace in the 21st century. Some of the ills have been mentioned: economic and environmental challenges, unemployment issues, amongst others. Historical analysis of each nation differs; so also does their political, social, and technological makeup. From history, each nation has developed at a different time; and this has affected the political, social, and technological structures. Accompanying these differences, are various systems of education aligned with their history. Individual countries will therefore approach STEM education uniquely, since the educational system in each country is particular to its needs.

STEM education is as a vital part of general education. STEM literacy is essential in uplifting the general populace (Department for Education and Skills, 2006). STEM education also seeks to increase STEM skills for everyone (Holdren, 2009). STEM education is a tool for developing the entire population of the country. Felix and Harris (2010) showcased the relationship between the subjects in STEM education. The researchers commented that the application of engineering and technological design has been a helpful tool in augmenting the active engagement of students. STEM has helped in fostering learning and transfer in science and mathematics. The overall importance of STEM education, as revealed by Holdren (2009), includes revitalising the learning environment and the curriculum with real-life experiences; quickening learners' desire to explore, investigate, and know their world; boosting learners' confidence and self-direction as they navigate their workplace both individually and collaboratively; promoting children's excitement to learn mathematics and science, leveraging on the tools of technology, innovation, design, and engineering; boosting technological literacy for all; intensifying the ability of students to think with confidence and flexibility; making education more relevant, while reducing the rate of dropout from educational institutions.

An overview of machine learning

In 1959, Arthur Samuel defined machine learning as a discipline of study that enables the computer to learn without being explicitly programmed (Simon, 2013). This makes the computer a super-versatile tool for various functions, in line with the direction of the user. This also allows for less programming by the user of machine learning. A formal definition of machine learning was provided by Tom M. Mitchell, as "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 E" (Mitchell, 1997, p. 3). This definition highlights the functional values of machine learning, including those related to experience, performance, and tasks. Machine learning is important for solving tasks categorised into three broad classes, on the basis of the learning signal or feedback. These are supervised learning, unsupervised learning, and reinforcement learning (Russell & Norvig, 1995). In supervised learning, the computer is given example inputs, together with what the output will look like, to facilitate a process that results in input to output. In unsupervised learning, there is freedom for the learning algorithm to find the requisite structure in its input, which allows for discovering hidden patterns in data. Reinforcement learning allows a computer programme to interact with a dynamic environment; for example, trying to learn a game by playing against an opponent (Bishop, 2006).

The concept of machine learning stems from the subfield of computer science (Britannica). Machine learning is based on pattern recognition and computational learning theory in artificial intelligence. With the immense benefits data has to offer, machine learning seeks to understand the structure and study of algorithms, which can help to ascertain and make predictions on data (Kohavi *et al.*, 1998). This demonstrates the importance of machine learning as a vital tool for heuristic and prediction purposes, as it allows learning to take place together with informed decisions, using data. The data-informed decision is a model built from the input (Bishop, 2006: Kohavi *et al.*,1998). The multi-versatility of machine learning is seen in many areas of computing, such as spam filtering, and optical character recognition (OCR) (Wernick *et al.,* 2010), search engines, and computer vision. Machine learning and data mining are closely related (Heikki, 1996). From an industrial standpoint, machine learning can be referred to as predictive analysis or predictive modelling.

Challenges of STEM education

STEM education is constrained by many challenges. Tikly *et al*. (2018) highlighted some of the challenges of STEM education. Key among the impediments is the shortage of qualified teachers in the discipline. STEM education, as a discipline, relies on qualified teachers to effectively discharge knowledge to students. The need for qualified teachers was attributed to increased enrolment in secondary education. When unqualified teachers are employed to teach STEM education, STEM subjects will still seem difficult to comprehend. Tikly *et al*. (2018) further maintain that, in the sub-Saharan context, there is difficulty in factoring in the various stages of learning in individuals into the whole educational mix. Classes are often large. This does not allow for teachers to focus on individual learning abilities of students, so as to adequately address their needs. Also, STEM disciplines are capital intensive, making huge demands in terms of resources necessary for its delivery. For effective delivery of STEM education, there must be computers, laboratories, chemicals, textbooks, etc., which are not readily available in the sub-Saharan context. With the lack of necessary infrastructure key to the delivery of STEM education, teachers tend to depend on theoretical approaches to learning, without necessarily experimenting so as to have a better grasp of the discipline. There is also a societal aversion to STEM education in sub-Saharan Africa. This has engendered a widespread negative perception. According to Tikly *et al*. (2018), people are less confident of succeeding in STEM disciplines.

Imperative of machine learning in STEM education

In STEM education, machine learning can help to support new ways of delivering teaching materials to students, placing more emphasis on the online environment. Machine learning can also help teachers to provide learning plans tailored to the needs of individual students. This is confirmed in the works of (Abbeel, 2016), who maintained that machine learning systems can help in automatically comparing a student's answer with those of his peers. In situations in which there is a lag, the machine directs the student to the resources needed for studying a particular area. Machine learning is characterised by the flexibility to tilt towards the needs of the learners by focusing on algorithms derived from massive datasets. Machine learning shows how receptive students are to information, together with their learning speed. These factors ensure that learning can only be said to have taken place when previous information has been understood by the students. This also ensures that all students are considered, and no one is left behind. Machine learning is vital in STEM education in analysing content delivered to students, using machines to instruct students. The machine-learning approach to analysing content focuses on the information the teacher uses, determining whether it is necessary to satisfy the learning needs of the students, while respecting the applicable standards. The machine-learning approach also determines whether the information and content delivered to the students meets the intellectual strength of specific students. A large amount of data is generated in various fields of science. Machine learning is vital in processing such data sets. Machine learning is important in extending the boundaries of science. With the application of machine learning, these datasets will be applied by researchers in STEM education to analyse their datasets. In neurosciences, machine learning influences modern neuroscience through data analysis (Kass, Eden, & Brown, 2014) and through modelling techniques (Yamins, & DiCarlo, 2016).

Machine learning is also applied on educational platforms, leading to adaptive learning platforms. Knewton is one of the largest adaptive learning platforms used by more than 10 million students globally, either separately, or with some custom-made local platforms. Knewton has a wide user base across South America, Europe, Africa, Asia, and Australia. This adaptive learning platform has improved students' retention and academic performance. However, there are tensions about how these milestones were achieved (Ferguson *et al.*, 2016). Other learning platforms include GoLab and Nextlab, which are online experimental virtual labs supporting inquiry learning, and providing new, interactive ways of conveying knowledge to students. These learning platforms are vital in STEM education. Interactive platforms provide the opportunity for answering students' needs and concerns in STEM education. Third-space learning has its specialty in mathematics and school leadership, which are also constituents of STEM education. The application of third-space learning has resulted in an improvement in mathematics.

Machine learning is used in STEM education's massive open online courses (MOOCS). The application of machine learning in MOOCS is to analyse inputs of students, grading and scoring students, and their computer-based assignments. Machine learning, according to (Hollands, & Tirthali, 2014) allows MOOC handlers to provide support for students, using human resources for more profitable ventures. Machine learning is important in the educational sector, and it is vital in enhancing learning outcomes of students. The components of machine learning are used in planning, implementing, evaluating, following up, and developing objectives (Lv & Li, 2015). According to Chounta (2019), evaluating students in STEM education is imperative. Machine learning offers a viable application for student modelling and personalised feedback. Computational methods in machine learning are used to assess students' background knowledge, to evaluate students' knowledge, and to presage their future performance. It is important to grasp students' knowledge in order to develop appropriate learning platforms that will ensure that knowledge is delivered to the recipient of learning. This guide learning processes, making them effective. Bloom (1984) confirms that the indications are applicable in shaping the learning perspectives of students, providing adaptive, personalised feedback custom-made for the needs of the learners. Chounta (2019) further maintains that machine learning also provides intelligent methods that filter study materials and learning activities, factoring in the learners' interests and needs.

It is a Herculean task to cope with large numbers of students, evaluating them to determine their performance. Much tedious work is demanded of the teacher. A better standardization system in STEM education will reduce the stress associated with scoring students. Automated essay scoring is vital, which is one of the most promising applications of machine learning in education. Automated essay scoring (AES) is a robust application of artificial intelligence in education, using machine learning. Manually reading, scoring, and recording can be overly demanding and time-consuming. This makes many teachers reluctant to assign writing projects to their students. The major aim for AES is to score students' writing, which includes tests, assignments and exams for larger populations, such as lecture-based college courses, and for entrance examinations into higher institutions of learning. This is in line with the findings of Stone *et al.* (2016), who maintained that massive open online courses (MOOCS) applied automated scoring engines to their system to grade thousands of people learning on their platform. The efficacy of automated essay scoring has been proven to be on a par with humans, on standard writing tasks (Powers et al., 2001; Kolowich, 2014.)

In education, there are both active and passive learners. The active learner maintains an intimacy with the learning environment during lectures, whereas a passive learner is a receptor of information from the environment, without necessarily influencing or altering it. For learning to take place effectively, there must be interaction between the learners and the environment. Both paradigms used for active and passive learning vary according to the role played by the learner. Machine learning, as a field, deals with these differences in learners to ensure that the major goal of the teaching and learning is achieved.

Conclusion and recommendation

The acronym STEM (science, technology, engineering, and mathematics) has been adopted by various programmes as a major focus for renewed global competitiveness. The world we live in is one based on innovation and knowledge. For people to thrive in it, they must constantly align with these changes taking place. The STEM workforce will remain pivotal to our economic growth, contributing to innovation, technological growth, and economic development. Science and technology have been central players in maintaining positive economic growth and well-being among the citizens. Findings of this study reveal that, with the changes manifested in the global sphere generally, it is important to leverage STEM education. More focus on some emerging technologies such as artificial intelligence and machine learning, will promote ample benefits from STEM education. The immense benefits of machine learning, as a technology, cannot be questioned. From the study, it has been proven that this can support new ways of delivering teaching materials to students. More emphasis is now placed on the online environment. Teachers can provide learning plans tailored to the needs of individual students. This will enhance the conducting of education, fostering students' learning outcomes by providing support that will increase innovation and creativity. It will reduce the time and stress associated with the rigours of teaching, by providing a better standardization system in STEM education. Stress associated with scoring students will be ameliorated. Future behaviour and performance among students can be predicted, and the old methods of education will change (Abbeel, 2016; Kass, Eden, and Brown, 2014; Ferguson *et al.,* 2016; Powers *et al.,* 2001; Kolowich, 2014.)

In this paper, an overview of machine learning and STEM education, together with machine-learning practices used in STEM education contexts was provided. Also, a short historical overview of STEM education and machine learning, and the imperative of machine learning on STEM education was presented. The challenges that face machine learning were also carefully examined in this paper. In response to these obstacles, the paper theorises the multifaceted benefits of machine learning in STEM education. Benefits include delivering apposite tools for stakeholders in education to choose effectively and efficiently the most appropriate resources and content that meet their learning standards. Such will ensure adaptation and customization of learning content to satisfy individual learners. This will provide a better means for evaluation, grading, and scoring students.

Technology is everywhere. It is important in the educational sector, with emphasis on STEM education. Machine learning has become a new template for education, being an innovation that controls artificial intelligence and human interaction. Machine learning has opened incredible possibilities within STEM education. This implies that future learning environments will be shaped by and are likely to be highly specific to individual learners' needs, in a bid to help them realise such needs, fostering their potential. With the immense benefit machine learning poses for STEM education, it is vital to intensify efforts to support machine-learning strategies in the educational sphere. Such can be achieved by incorporating elements of machine learning into the educational curriculum. Machine learning is also predicated on availability of data. It is imperative that cloud-based, large structures offer centralised access, not only to pedagogical materials, but also to user data, and computational tools necessary for machine learning. There must be synergy and a bottom-to-top approach in integrating machine learning into STEM education. This will ensure that all stakeholders vital to the teaching-learning curve are considered in the whole dynamics. If good design factors in all the stakeholders, the technologies will be applicable to the context of learning. This will also ensure that there is no disconnect between the learning needs and emerging technologies and platforms for machine learning. To leverage the immense opportunities and benefits machine learning has to offer in STEM education, it is therefore recommended that adequate support be provided to stakeholders in the educational value chain. Teachers, students, policymakers, inter alia, must become more familiar with machine learning as a concept, and in practice. Capacity-building workshops should also be provided for these stakeholders, to ensure that they are properly oriented to adopt machine-learning approaches in their classrooms, with minimal stress. In future, machine learning will come with more sophistication that will improve learning in the STEM education context. There are possibilities of developing multiple chatbots that will provide on-the-spot solutions to learners' needs. Also, virtual assistants will respond to the concerns of all stakeholders in the educational mix. There will be advanced algorithms leveraging the power of large datasets.

References

Abbeel, P. 2016 Machine learning for education (NIPS 2016 workshop). See https://dsp.rice.edu/ ml4ed_nips2016 (accessed 22 March 2017).

Bishop, C. (2006). *Pattern Recognition and Machine Learning*. London: Springer.

Department for Education and Skills. (2006) Science, Technology, Engineering and Mathematics (STEM) Programme Report. London: Department for Education and Skills.

Felix, A. & Harris, J. (2010) A project-based STEM integrated alternative energy team challenge for teachers. *The Technology Teacher*, 70(1), 29-34.

Ferguson, R., Brasher, A., Clow, D., Cooper, A., Hillaire, G., Mittelmeier, J., … Vuorikari, R. (2016). Research evidence on the use of learning analytics: Implications for education policy. Seville: European Union.

Henriksen, D. (2017). 'Creating STEAM with Design Thinking: Beyond STEM and Arts Integration,' *The STEAM Journal*, 3 (1), 1-11.

Henriksen, D. (2014) 'Full STEAM Ahead: Creativity in Excellent STEM Teaching Practices,' *The STEAM Journal*, 1 (2), 1-14.

Holdren, J. (2009) *STEM Initiatives*. Retrieved on the 20 January 2019 from http://www.eschoolnews.com/2009/11/24/obamalaunches-

Hollands F, & Tirthali D. (2014). MOOCs: expectations and reality. Columbia University, NY: Center for Benefit-Cost Studies of Education, Teachers College.

Holley, K. M. (2009). Understanding interdisciplinary challenges and opportunities in higher education. ASHE Higher Education Report, 35(2), 1-131.

Chounta, I. (2019). A review of the state of art of the use of machine learning and artificial intelligence by educational portals and OER repositories. Brussels: European Schoolnet.

Jolly, A. (2014). STEM vs STEAM: Do the arts belong? Education Week Teacher, 1-3.

Jonassen, D. H., & Carr, C. S. (2000). Mindtools: Affording multiple knowledge representations for learning. Computers as cognitive tools, *2*, 165-196.

Jonassen, D., Strobel, J., & Gottdenker, J. (2005). Model building for conceptual change. *Interactive Learning Environments*, *13*(1-2), 15-37.

Kang, M., Jang, K., & Kim, S. (2013). Development of 3D actuator-based learning simulators for robotics STEAM education. International Journal of Robots, Education and Art, 3(1), 22-32.

Kass R, Eden U, Brown, E. (2014). Analysis of neural data. Berlin: Springer.

Kim, E., Kim, S., Nam, D., & Lee, T. (2012). Development of STEAM program Math centered for Middle School Students. Retrieve on 20 December 2019, from: http://www.steamedu.com/wpcontent/uploads/2014/12/Development-of-STEAM-Korea-middle-school-math.pdf (accessed: 30/6/18)

Kim, H. & Chae, D.H. (2016) The Development and Application of a STEAM Program Based on Traditional Korean Culture, EURASIA J. Math., Sci Tech. Ed, 12(7), pp.1925–1936.

Kolowich, S. (2014). "Writing Instructor, Skeptical of Automated Grading, Pits Machine vs. Machine," *Chronicle of Higher Education*, accessed on October 30, 2018, from https://www.chronicle.com/article/Writing-Instructor-Skeptical/146211

Lv Z, & Li X. (2015). Virtual reality assistant technology for learning primary geography. Amsterdam: Springer International Publishing.

Mannila, H. (1996). *Data mining: machine learning, statistics, and databases*. Int'l Conf. Scientific and Statistical Database Management. IEEE Computer Society.

Mitchell, T. (1997). *Machine Learning*. New York: McGraw Hill.

Morrison, J. & Bartlett, B. (2009). STEM as a curriculum: An experimental approach. *Curr. Opin. Neurobiol*. 20, 251–256.

Murphy, R. F. (2019). Artificial Intelligence Applications to Support K–1 2 Teachers and Teaching. RAND Corporation, DOI: https://doi. org/10.7249/PE315.

Office of the Press Secretary. (2009). Fact sheet: The race to the top. Retrieved from https://www.whitehouse.gov/the-press-office/fact-sheet-race-top

Ogunleye, J. & Tankeh, A. (2006) Creativity and innovation in IT Industry: an assessment of trends in research and development expenditures and funding with particular reference to IBM, HP, Dell, Sun, Fujitsu and Oracle, *Journal of Current Research in Global Business*, vol. 9, 14, pp 75-85

Oner, A. T., Nite, S. B., Capraro, R. M., & Capraro, M. M. (2016). 'From STEM to STEAM: Students' Beliefs About the Use of Their Creativity,' *The STEAM Journal*, 2 (2),1-14,

Osoba, A., & Welser, W. (2018). *An Intelligence in Our Image: The Risks of Bias and Errors in Artificial Intelligence*, Santa Monica : RAND Corporation.

Powers, D., Burstein, J., Chodorow, M., Fowles, M., & Kukich, K. (2001). *Stumping E-Rater: Challenging the Validity of Automated Essay Scoring*, Princeton, N.J.: Educational Testing Service.

Ramirez, A. (2013). 'Creativity is the Secret Sauce in STEM'. Accessed on 19 November 2019, from : https://www.edutopia.org/blog/creativity-secret-sauce-in-stem-ainissaramirez

Kohavi, R. & Provost, F. (1998). "Glossary of terms". *Machine Learning* **30**: 271–274

Russell, S. Norvig, P. [1995]. *Artificial Intelligence: A Modern Approach* (2nd ed.). New York: Prentice Hall.

Sanders, M. (2009) STEM, STEM education, STEMmania. *The Technology Teacher*, 68(4), pp.20-26

Simon, P. (2013). *Too Big to Ignore: The Business Case for Big Data*. Wiley. p. 89. ISBN 978-1-118-63817-0.

Stone, P., Brooks, R., Brynjolfsson, E., Calo, R., Etzioni, O., Hager, G., Hirschberg, J., et al, (2016). *Artificial Intelligence and Life in 2030— One Hundred Year Study on Artificial Intelligence: Report of the 2015–2016 Study Panel*, Stanford: Stanford University,

Tankeh, A. & Ogunleye, J. (2007) The Server Market: Innovation, Competitive Performance and Optimal Strategy in the face of 'Disruptive Innovation', *Conference Proceedings (Peer-Reviewed), 19th Annual Conference of the Association for Global Business*, Nov 15-18, 2007, Washington DC, USA.

Tarnoff, J. (2010). STEM to STEAM -- Recognizing the Value of Creative Skills in the Competitiveness Debate. Retrieved on the 23 of November 2019, from : http://stematehs.pbworks.com/w/file/fetch/46306554/STEM2STEAM_Creativity.pdf (accessed: 30/6/2018)

Tomei L. (2013). Learning Tools and Teaching Approaches through ICT Advancements. Hershey, PA: Information Science Reference. The Partnership for 21St Century Skills www.21stcenturyskills.org

Turner, K. B. (2013). Northeast Tennessee Educator's Perception of STEM Education Implementation. Dissertation. East Tennessee State University.

Voosen, P. (2017). "How AI Detectives Are Cracking Open the Black Box of Deep Learning. Accessed on the 16 June 2019, from; http://www.sciencemag.org/news/2017/07/how-ai-detectives-are-cracking-open-black-box-deep-learning

Wernick, Y., Brankov, Y. & Strother, Y. (2010). Machine Learning in Medical Imaging, *IEEE Signal Processing Magazine*, vol. 27, no. 4, July 2010, pp. 25-38

White, D. W. (2014). 'What Is STEM Education and Why Is It Important?', *Florida Association of Teacher Educators Journal*, 1 (14). pp. 1-9.

Williams, P.J., & Williams, A. (Eds.) (1996) *Technology Education for Teachers*. Melbourne: Macmillan.

Yamins D, & DiCarlo J. 2016 Using goal-driven deep learning models to understand sensory cortex. *Nat. Neurosci*. 19, 356–365.

Tikly, L, Jourbert, M, Barrett, A.M, Bainton, D, Cameron, L & Doyle, H. (2018). Supporting Secondary school STEM Education for Sustainable Development in Africa. Bristol: University of Bristol