Implementing Machine Learning Opportunities in Elementary School Settings

Simon Ellis, Andrea McGeorge and Celeste Puccio[1]

University of Colorado, Colorado Springs

Abstract:
Machine learning has become widespread in recent years. It is more often discussed on university campuses in computer science and engineering classes rather than in elementary schools. In studying educational applications of machine learning, the research is limited in scope for the elementary level. We have explored and researched this topic in order to develop and create both staff presentations and differentiated learning engagements for (k-5) students that begin to teach foundational concepts of machine learning and create greater excitement for computer science amongst elementary-aged children. It has been our intent, with this study, to develop learning engagements using some of the basics of the machine learning process in building knowledge and skills in young students.

Index Terms:
machine learning algorithms: a method of organizing data, giving computers the ability to learn without being explicitly programmed.
data mining: computational process of discovering patterns in large data sets.
constructivist learning: students construct understanding and knowledge through experiencing & reflecting on those experiences.

I. Introduction

"Machine learning is a computer's ability to learn from data, and one of the most useful tools we have to develop intelligent systems and applications … Data mining extracts information and finds patterns that can then be processed and communicated." –Geoffrey Gordon, Carnegie Mellon University.

Machine learning is used widely today for all kinds of tasks, from a web search, to voice commands, to robotics. It's hard to find an avenue that cannot benefit from machine learning in one way or another. Machine learning's intuitive, versatile, and focused approach to finding patterns in available data, and directing responsive reactions, makes it an asset for, as of yet, an unlimited number of applications. In today's world, it is more accessible than ever before, thanks to the variety of technology capabilities. Over the past decade, machine learning has given us self-driving cars, practical speech recognition, effective web search tools, and unique identification applications. To consider the information sorting ability it has provided for us in our everyday lives includes the benefit of email spam filtering, data delivery, preferential advertisements, and pattern/ image recognition [Witten, 1999].

Data mining is the process of discovering patterns in data … patterns must be meaningful and lead to an advantage when the data is in substantial quantities. "We are overwhelmed with data, every choice we make is recorded (and these are just personal choices … but also in commerce and industry choices). People frequently use data mining to gain knowledge, and not just predictions. (Witten et al. 2005)

The widespread application of the capabilities of machine learning in the educational setting have not yet been fully explored, nor have the responsibilities of these digital explorations been explained in their learning. Additionally, students today, no matter how unaware they may be, as to how a search engine is driven by machine learning, need to consider the underlying ramifications of soliciting or utilizing data derived through computer applications, both academic and those of social media.

The "Disinhibition Effect" gives students and adults alike a false sense of security, making them both comfortable and disarmed when sharing data online. (*BBC Radio4 –Technology July, 2016)* Our children are riding an implacable wave of technology! Whenever they go online, search the internet, send an email, keystroke on their computer, or make a phone call, their data can be organized and extrapolated to give important information to anyone who needs it, and writes code. This gives rise for the need of students to be aware of the consequences of their choices, and the reasons for cyber-security in this technological world of wonder.

II. Motivation

Introducing computer science at the foundational elementary level will bring about computer science awareness, with the long-term aim to increase the number of American citizens and permanent resident undergraduates who are attracted to careers in research & advanced studies in Computer Science. (Computer and Information Science and Engineering RET Supplements REU Sites)

Machine learning has been growing in importance in our lives and more importantly in our children's lives, as the profusion of devices increases each school year. It is a pressing issue for our students to both learn and be aware of both the benefits of data mining and the downsides of what that connection to the virtual world can mean. Children need to be aware that when they type data into the computer, that data can be analyzed by data mining, revealing more information than intended or that they are aware of. Each lesson will include the concept of awareness of the negative effects of data mining.

By analyzing Google Trends, it can be determined how often a particular search term(s) has been used. Internet searches for the terms "data mining" & "machine learning" reveal a trend. Data mining had been searched online more consistently than machine learning over the past fourteen years. However, over the last twelve months, there has been an increase in machine learning search requests, and they have surpassed requests for data mining. This concludes that people's interest in machine learning is growing as concerns for data mining are lessening. The graph below, figure 1, shows search requests for these phrases ('data mining' -top line, 'machine learning' -bottom line), since Jan 2004 until June 2016.

[1] Ellis, McGeorge and Puccio teach at Academy International Elementary School, in Academy School District 20, Colorado Springs, Colorado, USA. This work was supported by the 2016 Research Experience for Undergraduates (REU) program at the University of Colorado Colorado Springs (NSF Award No. 1359275).

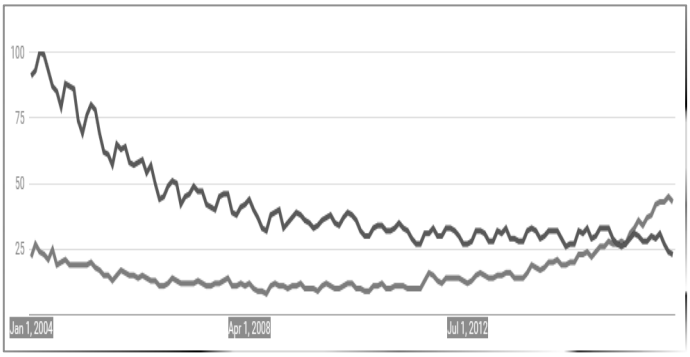

Figure 1. Search Request "Machine Learning & Data Mining

The Google Trends graph referenced that comparing the popularity of the two search terms "machine learning & data mining", also has the ability to display which countries in the world those searches were made from. Since 2004 until the present, the top six countries in order of search popularity have been for:

"Data Mining": Ethiopia, India, Nepal, Sri Lanka, Kenya, Singapore, and Hong Kong. See figure 2.

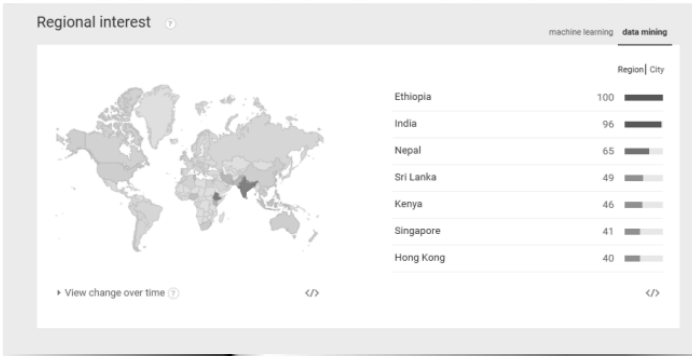

Figure 2. Search Request for "Data Mining" by Country

"Machine Learning": South Korea, India, Singapore, Hong Kong, Israel, Bangladesh, and Pakistan. See figure 3.

Figure 3. Search Request for "Machine Learning" by Country

Educational delivery of data mining, as demonstrated through computer algorithms, is an area that has been limited to individualized linear completion of tasks and assessments, within certain curriculum content [Rose& Rush, 2009]. For students to embrace the delivery of lesson instruction about computer science, it needs to be inviting, provocative, and self-motivating.

It is these gaps in the development of meaningful, interactive, practical applications that need to be investigated and developed to assure that students are participating in 21st century learning, and ready to embrace their futures. As written previously in this paper, educators need to remind students of their vulnerability in searching for, and in sharing data about themselves to the world, through the internet, regardless of their intent.

It is our intent, with this project, to develop a framework for learning in parallel with current standards of what modern day technology can do for students of all ages, and to scaffold instructional modules to allow for developing the mindset in ways that elementary educators today can only imagine. It is only now that new classroom innovations are being developed to utilize the science in those school settings.

The Computer Science Teacher Association Standards (CSTA) last revised in 2011 by The CSTA Standards Task Force laid out the following:

a) all students should have access to rigorous and culturally meaningful computer science and be held to high expectations for interacting with the curriculum.

b) diverse experiences, beliefs, and ways of knowing computer science should be acknowledged, incorporated, and celebrated in the classroom.

c) the integration of different interpretations, strategies, and solutions that are computationally sound enhance classroom discussions and deepen understandings.

d) the resources needed for teaching and learning computer science should be equitably allocated across groups of students, classrooms, and schools.

e) classroom learning communities should foster an environment in which all students are listened to, respected, and viewed as valuable contributors to the learning process.

f) ongoing teacher reflection about belief systems, assumptions, and biases support the development of equitable teaching practices.

The CSTA proposes a three-layer model for K–12 computer science that addresses the needs of the present and future by building on the lessons of the past. It focuses on fundamental concepts with the following five complementary and essential strands:

1. Computational Thinking

2, Collaboration

3, Computing Practice and Programming

4, Computer and Communications Devices

5, Community, Global and Ethical Impact

In figure 4 below, the process is illustrated as a cyclical experience of learning as do the learning engagements in the module presented in the appendix. These concepts drove our inquiry and development of the ideas featured in these lessons. Ultimately, these concepts will result in lifelong skills that will be applied in the computer science world of the students involved, who potentially are our future computer science leaders.

Figure 4. CSTA :Five Fundamental Concepts of Cyclical Learning

The CSTA divides up the k-12 continuum into three levels /ages: Level 1 (recommended for grades K–6) "Computer Science and Me". Level 2 (recommended for grades 7–9) "Computer Science and the Community".
Level 3 (recommended for grades 10-14) is split into three areas of importance: 'Computer Science in the Modern World', 'Computer Science Concepts and Practices', and finally 'Topics in Computer Science'.

The aim of the CSTA is that elementary school students are introduced to foundational concepts in computer science by integrating basic skills in technology with simple ideas about computational thinking. This parallels the educational spectrum of learning which students already experience throughout the curricular areas of literacy, mathematics, social studies and science. The learning experiences created from these standards will be inspiring and engaging, in so doing it will help students see computer science as an important part of their future world. The module of experiences is designed with a focus on active learning, creativity, and exploration. elementary, middle and high school. They have been used as a guide

The levels used by the CSTA gave us the scope and sequence in designing the module. (See appendix) These levels will also be used to help guide after school programs that explore computer science and machine coding. The focus of this paper is on the "Level 1" - elementary students K-6. However it should be pointed out that the school where this research will be primarily implemented is a K-5 institution.

Although these standards are thorough and were reviewed in 2011, they have still not been adopted by all states. This creates an obstacle of bringing computer science programs and standards to the k-12 level. Although the premise of this paper is to educate at a foundational level, for computer science at an elementary level, change needs to happen at the state level, so that standards can be integrated into the curriculum. However, events such as the upcoming Hour of Code in December, give hope for schools to offer meaningful computer science opportunities to the k-12 audience.

Community, Global, and Ethical Impacts

The ethical use of computers and networks is a fundamental aspect of computer science at all levels and should be seen as an essential element of both learning and practice. As soon as students begin using the internet, they should learn the norms for its ethical use. Academy School District 20, and CSTA talk extensively about the principles of personal privacy, network security, software licenses, and copyrights that must be taught at an appropriate level in order to prepare students to become responsible citizens in the modern world.

CSTA talks about students being able to make informed and ethical choices among various types of software such as proprietary and open source and understand the importance of adhering to the licensing or user agreements. In an elementary school, the level and exposure of computer usage is closely monitored, therefore this would become more of a concern at middle school. Students should also be able to evaluate the reliability and accuracy of information they receive from the internet. Throughout their educational experience students are presented with these challenges, and taught what best practice is, not just in technology. These standards introduce elementary school students to foundational concepts in computer science by integrating basic skills in technology with basic concepts about computational thinking.

The learning experiences in this module created from these standards are intended to be inspiring and engaging, helping students to become enthusiastic about computer science and see computing as an important part of their world. They are designed with a focus on active learning, creativity, exploration, inquiry and are typically embedded within other curricular areas such as social science, literacy, mathematics, and science.

III. Problem Definition

As a direct result of many states not adopting the CSTA standards, in conducting research of elementary educational models currently in use, there appears to be limited curriculum for computer science, specifically machine learning. Therefore, the focus of this study has been on building an understanding of the basic elements of computer concepts and applications for elementary age students in their daily lives.

Most recently, under new initiatives, funded through governmental agencies (federal, state and local) there has been an increase in both public and privately supported program development, with the intent of exposing students to, and providing avenues for, implementation of scientific and computer explorations, intentionally intended for younger populations. It is the hope, nationwide, that through these engineering based programs, students' interest will be piqued, and potentially open doors for further study. Admittedly, within the past few years, commercial programs have been developed that utilize the concept of machine learning and programming to instruct and entertain populations of all ages. However, there is much room left to establish a dedicated curriculum to lay the foundation for, and leave room for, the creativity embedded in uses of technology for elementary students. Lastly, in reference to initiatives sponsored by governmental agencies, (STEM/STEAM/National Science Foundation) great gains have been made in bringing the basics of science into assorted classrooms around the nation, with the intent to reduce the mystery and apprehension of using components of computer engineering in commonplace applications, and for all populations.

As mentioned earlier in this paper, computer science, more specifically machine learning, is a subject area that generally is not introduced at the elementary or even the middle school level. As participants and educators in our rapidly developing technological world, we are in a position to expose our students to material to help them build opportunities to access the global community, and its vast opportunities to build knowledge. With machine learning as the basis for developing certain science applications and predictors of results

in project based learning, we are empowering them to learn of the potential that technology holds in driving the future.

The primary research focus of this study, then, has been to investigate applications of technology relevant to the world of an elementary age student, and to provoke their curiosity as to, not only how it works, but how they could apply these new machine capabilities into their world.

It is also the authors' objective to insure students understand safety in the access and implementation of shared knowledge, within this world wide web of data. As teaching models, it is imperative that students are reminded to use caution when using their devices at school, as well as at home. Students also need to learn about how their digital footprint affects their lives, and to become aware of the rights and responsibilities of digital citizens.

In "Future Innovations in Science and Technology" (2003), Joseph Coates comments on the dramatic effect information technology will have over the next 25 years. Included within this broad swathe of a category are technologies promoting intelligence in systems and devices such as robots and virtual reality machines. Coates predicts that virtual reality (and other technologies) will cause massive changes in how we educate our students. Here we are halfway through that time-span and we are researching how best to present and teach elementary students about machine learning and data mining. (p252, Appendix C: The Concept of Change, "Patterns of Change" –College of William and Mary)

IV. Proposed Solution

By exploring recent developments in information gathering, voice controlled devices, and computer generated responses based on the premise of artificial intelligence, we've developed practical instructional modules to introduce students to some of the potential embedded in technology today. These lessons begin with building student curiosity as to the technological components of the programs they are familiar with, allowing hands-on provocation opportunities as part of the learning, in consideration of adapting to suit a range of elementary ages.

We've created a module which will introduce students to computer science concepts, specifically machine learning using the pedagogy of constructivist learning. What is meant by constructivist learning or constructivism? The term refers to a philosophy of education that learners construct knowledge for themselves. Each learner individually (and socially) constructs meaning, as they learn. The core ideas expressed by it have been clearly enunciated by John Dewey among others. "Constructing meaning is learning; there is no other kind. The dramatic consequences of this view are twofold; 1) We have to focus on the learner in thinking about learning (not on the subject/lesson to be taught). 2) There is no knowledge independent of the meaning attributed to experience (constructed) by the learner, or community of learners." [Institute for Inquiry, Exploratorium, San Francisco]. Constructivism is inquiry-based. If the students are asking questions, they are constructing meaning. It is our hope to help the students construct meaning by first connecting with their own background experience, which will then be used as a springboard for new connections and differentiated learning opportunities.

To begin, we gathered and created resources that helped build skills and confidence and energize the classroom with learning-by-doing opportunities. One of these was coding. "You can learn skills at any age but why wait when we can teach everyone to code now!" (Richard Branson Virgin Group) I. "Hour of Code", (5^{th}-11^{th} December, 2016). The 'Hour of Code' is nationwide initiative by Computer Science Education Week [csedweek.org] and Code.org [code.org] Its aim is to introduce millions of students to one hour of computer science and computer programming. This will allow students opportunities to code, including but not limited to: "Star Wars: Building a Galaxy with Code", "Minecraft Hour of Code", and "Code with Anna and Elsa".

Additional provocations and learning engagements will alert the natural curiosity of school age children. PLTW, Project Lead The Way, provides a transformative learning experience for K-12 students and teachers across the US. It catalyzes lifelong interest in STEM. Through "PLTW Launch" K-5 students & teachers learn and discover code together. [pltw.org] (UCCS is an affiliate institution PLTW)

Another practical exploration is the MaKey MaKey circuit boards. These are products from collaboration between SparkFun and Jay Silver/Eric Rosenbaum of the MIT Media Lab. They are "Invention Kits for Everyone." They enable the learner to play Mario on Play-Doh or Piano with Bananas. These circuit boards allow students to begin to understand the how and why of the connection of computer coding through making actual electrical connections which illustrates the way a computer behaves.

Another product in a similar vain is the Raspberry Pi. It is a series of credit card-sized single-board computers developed in the United Kingdom by the Raspberry Pi Foundation with the intent to promote the teaching of basic computer science in schools and developing countries. "Scratch" (is) included as standard with Raspberry Pi and it enables anyone to start programming within minutes, without any prior knowledge." (Phil King, The MagPi magazine). Python computer coding language is taught for students to program with.

Websites such as Tynker.com, also offer the chance for students to build and play their own game. "Tynker is a creative computing platform where millions of kids have learned to program and build games, Minecraft mods, apps and more. Tynker offers self-paced online courses for children to learn coding at home, as well as an engaging programming curriculum for schools."
(Tynker.com)

Cleverbot and Chatbot apps learn from answers to a "conversation it has, using machine learning embedded in its code." These apps will be perfect inquiry for students:

How do they work?
How do they learn?
How do they know what to ask?
What is it going to ask next?

There are also Chatbots using avatars such as –"Eviebot, Boibot, Chimpbot & Willbot". These apps will be introduced as provocations, but will be revisited as assessments at the end of the module to evaluate if students can share how these robots relate to machine learning.

Another resource which yielded positive insights into machine learning was the viewing of TED Talks for machine learning. It revealed the work of Prof Vijay Kumar at the University of Pennsylvania, his talks on "The Future of Flying Robots", and "Robots that Fly…and…Cooperate" helped demonstrate the extent to which this area of study and development has now reached with Prof Kumar, where he is the Dean for the School of Engineering and Applied Science. Daniel Ueda at Penn Engineering and the GRASP

Lab (General Robotics, Automation, Sensing and Perception Lab), helped the research with links and resources that his lab has used for similar research projects. Students are always readily engaged in lessons that involve robots.

CSUnplugged.org is another resource that "introduces computer science basics in a format that's fun & accessible to the youngest learners (grades K-5)" (code.org) "Children in their formative years (of elementary school), love learning through play." [qubizm.co.uk]. The easy & fun activities in this book, designed for students of all ages, introduce you to some of the building blocks of how computers work—without using a computer. "This book can be effectively used in enrichment and extension programmes, or even in the regular classroom. You don't have to be a computer expert to enjoy learning these principles with your students." (CSUnplugged). The book contains a range of activities, with background information explained simply. We have adapted some concepts and activities from this resource to help build our module as well.

The module we created can be found in the appendix. In the first lesson, students are presented with practical applications of machine learning they may be familiar with, such as iPads, smartphones, robots, drones and AI apps. Many of us use computers every day, but how do they work? How do they think? How can people write software that is fast and easy to use? Do machines make mistakes? Computer science is a subject that explores these very questions. This is the provocation in the first lesson. After this provocation, we have the students try to find patterns in translating words and phrases as a means of introducing data mining.

To introduce decision trees, we've designed a lesson that introduces a guessing method that predicts what the user is going to type next, as in machine learning. The computer suggests what it thinks the students are likely to type next, and they just indicate what they want. This sort of system is also used to 'type' texts on some cell phones.

Another learning engagement that introduces concepts of networks, shows how computers use networks to sort. This is a kinesthetic activity that the children can walk through to understand better.

We introduce another activity or game, the orange game, to demonstrate that sometimes you have to streamline data to make it work well in a network. There are problems in many networks, especially when data mining. Computer scientists spend a lot of time figuring out how to solve these problems and how to use networks that make the problems easier to solve and patterns easier to detect. If you can figure out how to make problems easier, they are more efficient.

The activity "Conversations with Computers" aims to stimulate discussion on the question of whether computers can exhibit "intelligence," or are ever likely to do so in the future, which is still a controversial topic that can lead to critical thinking and stimulating classroom discussions. Our hope is to convey to the students that machines make mistakes and we should always be critical thinkers.

The module culminates with a Vocabulary Jeopardy game, which is a review of the concepts and vocabulary taught in the module. This game will function as an assessment as well as an engaging culminating lesson.

V. Conclusion

At the conclusion of this research, developmentally appropriate, and somewhat guided instructional materials, have been tailored to curriculum appropriate for younger students. In learning the basis of computer programming and indeed, how a computer can actually perform the functions that it is capable of, the content of our lessons introduce basic understandings, and allow students to build their own investigations of how this tool of today can extend the capabilities of research and science of tomorrow.

Through the elements of precise and sound instructional design and implementation, and in exploring the documented advantages of constructivist learning, students today even at a young age, are in a position to grasp to some degree, the processes in technology that support the world as they know it. It is only with creative and provocative delivery that this content will become part of their thinking and lay the groundwork for future science based developments and inspirations.

Presently, all curriculums are standards-based and when states adopt computer science standards, the students will benefit from our original objective of getting more people involved in this movement towards computer science in the school.

Upon conclusion of this module, the students will be aware of machine learning and data mining and be able to express the implications, both positive and negative of this relatively new area of study.

In addition, we aim to provide meaningful presentations for school staff about both machine learning and data mining, so that they too can introduce some of these lessons or any of the concepts to their students. The expectation is that these learnings will enhance the technological awareness of this primary/intermediate age-group, which in turn, will increase the number of American citizens and permanent resident undergraduates who are attracted to careers in research and advanced studies in computer science.

Acknowledgments: Thank You to the following people for their help, questions and assistance with this research project; Dr. Jugal Kalita, Dr. Terry Boult, Tri Si Doan, Cora Coleman, Andrea Costas, David Foley, Abigail Graese, Nathan Harmon, Kamal Kamalaldin, Alanya Kennedy, Liam Schramm, Matthew Simpson, and Kyra Yee.

VI. References:

[1] Witten, Ian H. (1999) Data Mining: Practical Machine Learning/ Tools and Techniques. Pp.3-56.

[2] Harrington, Peter. (2011) Machine Learning in Action. Pp.18-49.

[3] Clifford, Miriam. *"20 Collaborative Learning Tips and Strategies for Teachers",* July 1, 2016. Teach Thought, www.teachthought.com/pedagogy

[4] *"Hands-On Activity- Cars: Engineering for Efficiency"*, May 2015. Teach Engineering: UC Boulder. www.teachengineering.org/lessons

[5] Yonge, P.K. *"Blended Learning: Making it Work in the Classroom",* September 11, 2014. www.edutopia.org.

[6] Rose, Joel, and Rush, Christopher. Teach to One: *School of One Program*, September 15, 2009. www. edweek.org/digitaleducation