Machine Learning for All – Introducing Machine Learning in K-12

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ABSTRACT

Although Machine Learning (ML) is integrated today into various aspects of our lives, few understand the technology behind it. This presents new challenges to extend computing education early on including ML concepts in order to help students to understand its potential and limits and empowering them to become creators of intelligent solutions. Therefore, we developed an introductory course to teach basic ML concepts, such as fundamentals of neural networks, learning as well as limitations and ethical concerns in alignment with the *K-12 Guidelines for Artificial Intelligence*. It also teaches the application of these concepts, by guiding the students to develop a first image recognition model of recycling trash using Google Teachable Machine. In order to promote ML education, the interactive course is available online in Brazilian Portuguese to be used as an extracurricular course or in an interdisciplinary way as part of science classes covering recycling topics.

KEYWORDS

Machine Learning, Computing Education, K-12

1 Introduction

Artificial Intelligence (AI), which until recently seemed something very distant and of limited access by professionals in technological areas only, today presents itself in common situations, such as spam filters, recommendation mechanisms, chatbots, digital assistants, GPS systems, etc. (Marr, 2019).

Considering this presence and the inevitable impact it has on daily activities, it is essential that people are prepared to deal with both current technologies and those to come. Thus, today, it is necessary to understand Artificial Intelligence not just a consumer, also as a creator of this type of innovation, since it is found practically everywhere (Touretsky et al., 2019)(Kandlhofer et al., 2016). Taking into account also the gap between the growing market demand for AI professionals and the number of professionals available, it is necessary to stimulate interest in careers in this area from an early age on (Forbes, 2019). It is necessary to demystify the idea that AI is complex and inaccessible and to promote initiatives that bring students closer to the understanding and

production of these technologies. Therefore, we can observe a trend worldwide to include Artificial Intelligence in K-12 curricula. Some countries like Australia and the United Kingdom show significant advances in this direction (Google for Education, 2019) and a considerable amount of AI courses for K-12 have emerged during the last years (Marques et al., 2020). Yet, so far, such efforts are still very scarce in Brazil without instructional units available in the native language as an essential requirement for its application on this educational stage.

According to the *K-12 Guidelines for Artificial Intelligence* by AI4K12 (Touretsky et al., 2019), AI education encompasses 5 big ideas, including Machine Learning (ML). This includes an understanding of basic ML concepts, as well as limitations and ethical concerns related to ML. And, aiming also at teaching the application of these concepts this covers the development of ML applications encompassing the main phases of a human-centric ML process (Amershi et al., 2019): data management, model learning, evaluation and deployment. In order to facilitate the learning progress of students in this complex knowledge area, the “Use-Modify-Create” cycle (Lyle et al., 2019) commonly used for the progression of learning computing concepts and practices, can also be adopted for ML education. Following this cycle, students start by first using and analysing a given ML model, then remix/modify an existing one, until creating their custom ML models.

Therefore, we present in this article the development of an introductory course to teach basic concepts of AI/Machine Learning as part of computing education in Brazilian schools addressing primarily middle and high school level. Assuming the current lack of ML competencies among K-12 students, we initially focus on the “use” stage only of the “Use-Modify-Create” cycle. In order to allow the adoption of the course in an interdisciplinary way in science classes, the course refers to recycling knowledge, contributing also to the fixation of this content.

2 The course “Machine Learning for All”

The course has been systematically developed following an instructional design process (Branch, 2009).

2.1 Context analysis

The course is focused on teaching ML to students in Brazilian schools aged 10 to 14 years old (middle school) and as well as being applicable as a first contact with ML in high school. On these educational stages, according to the contents established in the Brazilian National Curriculum, we can assume that students are literate in the native language (Brazilian Portuguese) and have some familiarity with the English language, but are not necessarily fluent in English. Regarding natural sciences, students should have developed collaborative thinking and high-level understanding of the natural, technological, and individual world and the relationships between them based on artifacts specific to the natural sciences. In general, students in middle school demonstrate an age-appropriate performance in writing, reading and understanding their experiences, so that they can expand their perception to analyse larger contexts in the following years (MEC, 2018).

According to data from Prova Brasil, 55% of 9th grade students in Brazilian public schools have at least one computer at home and 42% of them spend more than three hours a day using digital technologies. This presence of technology in the lives of students rises in the state of Santa Catarina in the south of Brazil to 75% and 60%, respectively (INEP, 2017). Thus, students of this age group regularly use the Internet, mobile phones and other technological devices, possessing skills with handling and the ability to learn to use the tools with ease. Specifically, in relation to the use of mobile phones in Brazil, the National Continuous Household Sample Survey indicates that, in 2018, 79.3% of people over 10 years of age had a mobile phone for use, mainly Android (Statcounter, 2019).

With regard to computing education, according to Bordini et al. (2016), computational thinking has started to be studied and introduced in Brazilian schools through individual projects since 2010.

Yet, most schools still address this issue by treating technology solely as a resource, teaching students to be users, but not necessarily technology creators. And, although there are several initiatives in Brazil aiming at amplifying computing education, it is still mostly limited to individual extracurricular programs (Silva et al., 2018). With respect to Artificial Intelligence and Machine Learning, the curriculum proposed by the Brazilian Computing Association suggests such contents are introduced only in high school in order to understand the fundamentals of artificial and robotic intelligence (SBC, 2018). Machine Learning, however, is not mentioned. Therefore, currently, in practice, AI/ML education on the middle-school level is basically non-existent in Brazil (FECAP, 2020).

According to data from the 2018 school census, 67% of Brazilian public schools have access to the Internet. In general, there are more than 900,000 computers available for student use. However, only 38% of schools have a computer lab. Specifically, in Florianópolis, however, the numbers are more positive: 100% of public schools have access to the internet, with 1,658 computers for students. Computer labs are generally coordinated by an educational technology teacher. These professionals typically have a background in pedagogy with some specialization in the technological area. The other subjects of the K-12 curriculum are taught by teachers in the respective area. However, also in Brazil, there is a lack of teachers qualified in computing education.

Typically, each class in Brazilian schools has a duration of about 45 minutes and the maximum number of students for middle school is 25 students, while 30 students for high school (Florianópolis, 2012).

2.2 Definition of the course

The course is targeted at students in middle school without any prior knowledge on Machine Learning. It is assumed that students already have some understanding of basic concepts of algorithms and programming and/or app development with App Inventor as part of previous coding classes. In relation to Machine Learning, the learning objectives are defined in alignment with the K-12 Guidelines for Artificial Intelligence (Touretsky et al., 2019) referring to Big Idea 3 – Learning and AI literacy as defined by Long & Magerko (2020), covering also some general computing topics as proposed by the CSTA (2017) (Table 1).

Table 1. Learning objectives of the course

ID	Learning objective	Knowledge area	Source
LO1	Know and identify examples of ML application	ML	(Touretsky et al., 2019)(Long & Magerko, 2020)
LO2	Describe basic ML concepts: what is a neural network, learning, ML process	ML	(Touretsky et al., 2019)(Long & Magerko, 2020)
LO3	Identify patterns in data	ML	(Touretsky et al., 2019)(Long & Magerko, 2020)
LO4	Simulate the training of a simple neural network	ML	(Touretsky et al., 2019)
LO5	Collect, clean and label data for the training of a ML model; understand how ML algorithms are influenced by data	ML	based on human-centric ML process (Armeshi et al., 2019)(Long & Magerko, 2020)
LO6	Train a ML model	ML	(Touretsky et al., 2019)(Long & Magerko, 2020)
LO7	Evaluate the performance of the ML model	ML	based on human-centric ML process (Armeshi et al., 2019)(Long & Magerko, 2020)
LO8	Deploy the ML model by developing a mobile app	ML/Algorithms and programming/User interface design	(CSTA, 2017: 1B-AP-12)

LO9	Discuss ethical concerns and the impact of ML on society	Impacts of computing/AI	(CSTA, 2017: 1B-IC-18)(Touretsky et al., 2019)(Long & Magerko, 2020)
LO10	Share the developed software system	Algorithms and programming	(CSTA, 2016: 1B-AP-12, 1B-AP-17, 2-AP-16)

In addition to providing the student with a perception of the application of ML in our daily life and a basic understanding of how ML works, it aims to take the student to the application level by using and analyzing a ML model on the recognition of recycling trash images. During the practical part, students go through the basic steps of a human-centric ML process, including data management, ML model training, and evaluation. The deployment of the created ML model is planned as an extra activity by creating a mobile app with App Inventor, enabling the student to create a functional and intelligent ML solution.

Aiming at the possibility of an interdisciplinary application, the ML to be developed focuses on the task of the recognition of images of recycling trash. In accordance with the Brazilian National Curriculum this topic is approached in K-12 (Table 2).

Table 2. Interdisciplinary learning objectives (science)

ID	Learning objective	Knowledge area	Source
LO11	Propose individual and collective initiatives to solve environmental problems in the city or community, based on the analysis of successful consumption and sustainable sustainability actions.	Life and evolution	(MEC, 2018: EF09CI13)

The course is organized in the following parts:

- General notions and relevance of ML
- Fundamental concepts
- Make your first ML model (with the additional activity “Make your recycling app!”)
- Content review and ML process
- Ethical issues and societal impact of ML

In the first part, AI/ML and its application in everyday life is motivated and illustrated through practical demonstration examples. Students are also stimulated to discuss AI applications present in their daily lives in order to perceive the relevance of this knowledge. Part two on fundamental concepts introduces core concepts and ideas of ML and neural networks. This also includes the illustration of data management and simulating learning in a simple neural network example.

The part “Make your first ML model!” directs students to develop a ML model for image recognition using Google Teachable Machine. Based on a pre-assembled dataset (with partly “messy” images), the students prepare the dataset, by organizing/labeling the images into recycling categories as well as cleaning the dataset. Then, they train the model. Once trained, they test the model with new images uploaded or captured via webcam, and analyze performance measures, including the accuracy table and confusion matrix presented by Google Teachable Machine. Interpreting the performance results, the students, if necessary, adjust the dataset and/or model training parameters in order to improve the model’s performance.

If appropriate in terms of time availability and learning goals, an additional activity can be added in which the students integrate the developed ML model into a mobile application to be built with App Inventor.

Once having applied the ML process, basic concepts and the main phases or the process are revised. The last part of the course includes a critical discussion and reflection on ethical issues and societal impact of ML as well as the motivation with respect to career opportunities in this area.

Table 3. Course syllabus

Class	Content	Learning objective(s)	Classroom application		
			Educational method	Educational material	Assessment
General notions and importance					
1. (2h)	Motivation on AI and its application in daily life	LO1, LO9	Lecture, discussion, hands-on demonstrations	Slides 1.1, Demonstration: Object Detector and Classifier app, Quick, draw! game, video: Object detection and segmentation	Quiz
Basic concepts					
2. (2h)	Basic concepts of ML: what does it mean to “learn”, ML process: data preparation (collection, cleaning, labeling), feature engineering, training	LO2, LO3, LO4	Lecture, <i>unplugged</i> activity	Slides 2.1, instructions of unplugged activity	Quiz
Make your first ML model (and app)!					
3.1 (1h)	Classification of recyclables; data preparation (cleaning and labeling)	LO3, LO5, OA11	Lecture, hands-on activity (in pairs)	Slides 3.1, dataset, Google drive	Quiz, performance-based assessment of the dataset prepared
3.2 (1h)	Training of the model and evaluation	LO4, LO6, LO7	Lecture, hands-on activity (in pairs)	Slides 3.2, Google TM, evaluation worksheet	Quiz, performance-based assessment of the model and evaluation analysis & interpretation
Extra activity (4h)	<i>Deployment</i> of the created model in an app (<i>wireframe</i> available), customization of the app	LO8	Hands-on activity (in pairs)	Slides 3.3, <i>wireframe</i> of the app Recicle!	Performance-based assessment of the created app
Extra activity (1h)	Sharing of the created app	LO10	Hands-on activity (in pairs), presentation and discussion	Slides 3.4	Performance-based assessment on the sharing
Review of content and ML process					
4.1 (1h)	Revision of the ML concepts and process	LO1, LO2, LO5	Lecture, discussion, practical activity in pairs	Slides 4.1	Quiz
Ethical issues and societal impact of ML					
4.2 (1h)	Ethical issues with respect to AI/ML, limitations, risks and job opportunities	LO1, LO9	Lecture, discussion	Slides 4.2, demonstration: MIT Moral Machine, debate cards	Participation in the debate

The course can be applied in a face-to-face learning mode either as an extracurricular course or in an interdisciplinary way as part of science classes. It can also be applied in an online distance mode, accessing an interactive course version available online. The online distance version of the course contains the quizzes and other assessment instruments in a simplified way as part of interactive presentations, including multiple-choice questions, drag-and-drop exercises, etc.

Learning assessment

The assessment of the students’ learning is done in different ways (Table 4). This includes:

- Quizzes: simple quizzes (with up to 4 multiple-choice questions, drag-and-drop exercises, etc.) applied at the end of each class (or throughout interactive presentation in the online version of the course)
- Performance-based assessment based on the artefacts created by the students as learning outcomes. For each of the performance-based assessments a rubric is defined aiming at an automated feedback to the student.

Table 4. Student’s learning assessment

ID	Learning objective	Knowledge area	Assessment
LO1	Know and identify examples of the application of ML	ML	Quiz 1
LO2	Describe basic ML concepts: what is a neural network, learning, ML process	ML	Quiz 2
LO3	Identify patterns in data	ML	Quiz 2
LO4	Simulate the training of a simple neural network	ML	Quiz 2

LO5	Collect, clean and label data for the training of a ML model; understand how ML algorithms are influenced by data	ML	Quiz 3, Prepared dataset
LO6	Train a ML model	ML	Quiz 4, Training parameters/ML model
LO7	Evaluate the performance of the ML model	ML	Quiz 4, Evaluation report
LO8	Deploy the ML model by developing a mobile app	ML/Algorithms and programming/User interface design	
LO9	Discuss ethical concerns and the impact of ML on society	Impacts of computing/AI	Debate
LO10	Share the developed software system	Algorithms and programming	
LO11	Propose individual and collective initiatives to solve environmental problems in the city or community, based on the analysis of successful consumption and sustainable sustainability actions.	Life and evolution	Quiz 3, Prepared dataset

Table 5. ML Rubric – Use stage

Criterion	Performance levels		
	Poor - 0 pt	Acceptable - 1 pt	Good- 2 pt
Data management (LO5)			
Quantity of images	Less than 5 images per category	6 to 10 images per category	More than 10 images per category
Relevance of images	Several images are not related to the ML task (irrelevant) and/or at least one image contains unethical content (violence, nudity, etc.)	One image is irrelevant and no image containing unethical content	All images are related to the ML task and no image containing unethical content
Distribution of the dataset	Quantities of images by category vary greatly	Quantities of images by category vary little	All categories have the same quantity of images
Labeling of the images	Less than 20% of the images have been labeled correctly	Between 20 and 99% of the images have been labeled correctly	All images were labeled correctly
Data cleaning	There are several messy images (out of focus, several objects in the same image, etc.)	There is one messy image	No messy images were included in the dataset
Model training (LO6)			
Training	The model was not trained	The model was trained using standard parameters	The model was trained with adjusted parameters (e.g., epoch, batch size, learning rate)
Interpretation of performance (LO7)			
Tests with new objects	No object tested	1-2 object tested	More than 2 objects tested
Interpretation of tests	Wrong interpretation	-	Correct interpretation
Accuracy interpretation	Categories with low accuracy are not identified correctly and incorrect interpretation wrt. he model	Correctly identified categories with low accuracy, but incorrect interpretation wrt. he model	Correctly identified categories with low accuracy and the consequent interpretation wrt. he model
Interpretation of the confusion matrix	Misclassifications are not identified correctly and incorrect interpretation wrt. he model	Correctly identified misclassifications, but incorrect interpretation wrt. he model	Correctly identified misclassification and the consequent interpretation wrt. he model
Adjustments / Improvements made	No new development iterations have been reported	A new iteration with changes to the <i>dataset</i> and/or training parameters has been reported	Several iterations with changes to the <i>dataset</i> and/or training parameters were reported

2.2 Development of the course material

In accordance with the course objective and syllabus, educational material has been developed in Brazilian Portuguese as summarized in Table 6.

Table 6. Educational materials
Teacher material

including course syllabus, rubrics etc.

Slides

Support material for the unplugged, practical activities and debate

FICHAS DE DEBATE

- 1) Cada trió/dupla (dependendo do número de alunos da classe) pega uma ficha e discute sobre o tema, chegando numa resposta de comum acordo.
- 2) Após todos os grupos terem discutido separadamente, voltam ao grande grupo e compartilham perguntas + resposta a fim de que os outros alunos expõem suas opiniões sobre o tema, concordando ou discordando das respostas dos colegas.
- 3) Importante reforçar que não existe resposta certa ou errada, todas essas são questões muito subjetivas que animam o debate inclusive entre os especialistas da área.

Quem se responsabiliza por um acidente causado por um carro auto-dirigível?	Inteligência Artificial vai se tornar mais inteligente que os humanos?	Quais atividades computadores já executam melhor do que humanos?
Máquinas podem usar dados pessoais de humanos para aprender?	Inteligência artificial poderá substituir humanos em todos os trabalhos?	Inteligência Artificial pode julgar casos como um juiz?
Quais regras você definiria para um robô?	Você confiaria em um robô para tomar decisões por você?	Qualquer pessoa pode programar um computador para tomar decisões?
Um médico pode ser substituído por uma máquina?	Você acha que máquinas podem um dia definir suas próprias regras - ignorando as dos humanos?	Um político pode ser substituído por uma máquina?

Indication of online demonstrations and tools

such as Google Teachable Machine, MIT Moral Machine etc.

KAHOOT!

INSTRUÇÕES:

- 1 - Acesse <https://kahoot.com/schools-us>, crie uma conta e se primeiro jogo
- 2 - Insira as perguntas com as alternativas indicadas abaixo
- 3 - Salve o jogo para ser usado na hora da aula
  - no Youtube existem vários tutoriais sobre como utilizar o Kahoot, caso necessário!
- 4 - Na aula, entre na sua conta, inicie o jogo e pegue o PIN (número fornecido que vai possibilitar o acesso dos alunos ao jogo)
- 5 - peça para os alunos acessarem <https://kahoot.it/> e inserir o PIN

QUESTÕES

- 1) Para ensinar a rede, devemos alimentá-la com muitos exemplos
a) verdadeiro
b) falso
- 2) Durante a alimentação (treinamento) da rede, não precisamos dar uma rotulação aos dados, pois a rede consegue identificar sozinha!
a) verdadeiro
b) falso
- 3) A limpeza dos dados serve para excluir aqueles dados que não conseguiram ensinar a máquina muito bem.
a) verdadeiro
b) falso
- 4) Na limpeza de dados, devemos excluir fotos
a) compostas por mais de um elemento e nítidas
b) bem iluminadas e nítidas
c) tremidas e compostas por mais de um elemento
d) tremidas e bem iluminadas

Quizzes

The educational material as well as the course in an online version in form of interactive activities (Figure 1) at <http://cursos.computacaonaescola.ufsc.br/cursos/curso-mlparatodos/>.

Figure 1. Online course

3 Conclusion

The course “Machine Learning for All” was created with the objective of contemplating a current social demand: the dissemination of knowledge about Artificial Intelligence and, specifically, Machine Learning, starting in school. For this purpose, the course enables the teaching and learning of basic Machine Learning concepts in Brazilian schools, targeting primarily middle school and being also applicable as an introductory activity in high school.

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