Revista Brasileira de Informática na Educação – RBIE
Brazilian Journal of Computers in Education
(ISSN online: 2317-6121; print: 1414-5685)
http://br-ie.org/pub/index.php/rbie

Submission: 26/03/2025; 1st round notif.: 05/05/2025; New version: 11/05/2025; 2nd round notif.: 13/05/2025
Camera ready: 18/05/2025; Edition review: 07/07/2025; Available online: 07/07/2025; Published: 07/07/2025

Comparing the Perceptions of Middle and High School Students from Different Socioeconomic Status Backgrounds on Learning Machine Learning

Ramon Mayor Martins
Instituto Federal de Santa Catarina
ORCID: 0000-0002-1952-0909
ramon.mayor@ifsc.edu.br

Christiane Gresse von Wangenheim
Universidade Federal de Santa Catarina
ORCID: 0000-0002-6566-1606
c.wangenheim@ufsc.br

Marcelo Fernando Rauber
Instituto Federal Catarinense
ORCID: 0000-0001-5653-7155
marcelo.rauber@ifc.edu.br

Jean Carlo Rossa Hauck
Universidade Federal de Santa Catarina
ORCID: 0000-0001-6550-9092
jean.hauck@ufsc.br

Adriano Ferreti Borgato
Universidade Federal de Santa Catarina
ORCID: 0000-0001-6280-2525
adriano.borgatto@ufsc.br

Abstract
Machine Learning (ML) is increasingly integral to modern life, requiring its introduction to young individuals across all socioeconomic status (SES) backgrounds. Various initiatives are emerging for the integration of ML into the education of young students including the development of curricula, courses and activities. And although first applications indicate positive findings with regard to the students' learning, there still is a lack of research on the effect of such teaching efforts across students from different SES backgrounds. Therefore, this study investigates the impact of different SES backgrounds on the students' understanding and application of ML basic concepts through the application of the ML4ALL! course to 266 middle and high school students from different SES backgrounds. The findings reveal significant differences in students' understanding and explanation of ML concepts, indicating that this may be affected by their SES background. However, students' perceived ability to apply ML concepts and the perceived difficulty in learning ML were consistent across all groups. The results indicate that although the SES background may influence students' learning, it does not necessarily limit their perceived ability to engage with AI/ML concepts. The insights from this study may contribute to a better understanding of the perceptions of students from a low SES background regarding AI/ML learning and can assist in facilitating the development of inclusive, effective, and enjoyable educational approaches.
Keywords: *Machine Learning; Education; Socioeconomic Status; Perception; Middle School; High School.*

1 Introduction

Artificial intelligence (AI) is the science that allows machines to replicate human behaviors in an intelligent way (Russell; Norvig, 2016), and its integration into technologies has been steadily growing (UNESCO, 2022). Among these technologies is Machine Learning (ML), a subfield of AI that involves the process of machines learning from data, thereby continuously improving their performance (Mitchell, 1997). Currently, ML techniques are being widely applied in various fields, such as image recognition, object detection, facial recognition, medical image classification, and others (Visio.ai, 2024; Yu, 2023; Sharifani *et al*., 2023; Canada e Durães, 2020).

Cite as: Martins, R. M., von Wangenheim, C. G., Rauber, M. F., Hauck, J. C. R., & Borgato, A. F. (2025). Comparing the Perceptions of Middle and High School Students from Different Socioeconomic Status Backgrounds on Learning Machine Learning. Revista Brasileira de Informática na Educação, vol. 33, 605-631. https://doi.org/10.5753/rbie.2025.5751

The increasing use of AI and ML and their impact on the work environment highlight the urgency of preparing young people for this new era (UNESCO, 2022). Therefore, it is imperative to foster an understanding of ML among young students by introducing basic concepts and practices early on in order to not just create informed consumers of technology but also equipping them to be creators of intelligent and ethical solutions (UNESCO, 2022; Touretzky *et al.*, 2022). Educational strategies like these are key for enabling effective participation in the emerging technological landscape, which is growing professional opportunities (Touretzky *et al*., 2022; WEF, 2020).

Therefore it is also essential to ensure that AI/ML education is accessible to everyone. This includes adopting inclusive educational practices such as diverse teaching methods, curriculum design that caters to different learning styles, and the use of accessible technologies in AI and ML to overcome discriminatory attitudes and to promote equality (UNESCO, 2023). Recent efforts in this direction include the integration of AI into the education of young students, as seen in initiatives like AI4K12, AI4ALL, and TeachAI, alongside curriculum guidelines such as Erasmus+, AI+, and DAILy (UNESCO, 2022; AI4ALL, 2023; TeachAI, 2023; AI+, 2021; Lee *et al*., 2021). These programs, already implemented in various countries, including China, the United States, and the European Union, aim to impart basic AI/ML concepts and ethics (Casal-Otero *et al*., 2023; Zhou *et al*., 2023).

Despite these significant efforts, challenges remain, particularly for students from a low socioeconomic status (SES) background. SES is a multifaceted indicator of an individual's economic and social position, influenced by income, education, and occupation (Avvisati, 2020; APA, 2023). It affects access to resources, educational opportunities, and academic development (UNESCO, 2017; OECD PISA, 2019; Gretter *et al*., 2019; Vekiri, 2010). Students from lower SES backgrounds face numerous challenges in AI/ML education, including a lack of basic computing skills and limited access to required technology for their learning (Martins *et al*., 2023b; Martins & von Wangenheim, 2023; Freitas *et al*., 2025; Parker; Guzdial, 2015). In response, initiatives like MIT OpenCourseWare, CognitiveClass.AI, and Elements of AI are working to democratize AI/ML knowledge through free programs (MIT, 2023; IBM, 2023; Elementsofai, 2023).

Nevertheless, the specific challenges faced by students from a low SES background, which lead to a lack of interest and motivation, as well as their perceptions of their own learning process, have not been fully explored yet (Martins *et al*., 2023b; Martins; von Wangenheim *et al.*, 2023). Some studies investigate the impact of a low SES background on academic performance, specifically focusing on disparities in learning motivation and students' perceptions of their learning (UNICEF, 2021; OECD PISA, 2019; Chen *et al*., 2018; Vekiri, 2010). However, research focusing on these factors in relation to the effects of computing education, especially teaching AI/ML to students from a low SES background, remains scarce (Martins *et al*., 2023b; Parker; Guzdial, 2015; Vekiri, 2010). Vekiri (2010) found that while students from higher socioeconomic backgrounds tend to view the value of "Information and Communication Technology (ICT)" positively, those from lower SES backgrounds generally show less confidence in their ICT skills. On the other hand, Martins *et al*. (2023b) demonstrated that middle and high school students from a low SES background exhibited a positive perception of learning and felt motivated to learn AI/ML. Despite these findings, there are still gaps in the existing research, particularly in understanding the effects of AI/ML education for students from a low SES background. Thus, it becomes relevant to investigate whether the challenges encountered by students from a low SES background result in significant differences in perceptions of learning and perception of learning experiences in ML compared to their peers from other socioeconomic contexts, herein referred to as 'general SES' background.

Therefore, this study presents a comparative analysis of learning perceptions and experiences among students from different SES backgrounds in the context of the 'Machine Learning for All!' (a.k.a. ML4ALL!) course (Martins *et al*., 2023a). The analysis draws upon data collected from a total of 266 middle and high school students, encompassing both low SES and general SES backgrounds. By shedding light on the perceptions of students from low SES backgrounds regarding their own learning process and outcomes, this research aims to contribute to the creation of educational conditions that are not only effective but also more motivating, equitable, and relevant for these students.

This article is structured as follows: Section 2 presents the related works, Section 3 the research methodology. Section 4 presents the course context, Section 5 describes its applications, Section 6 evaluates the course applications, Section 7 presents the evaluation results, Section 8 discusses the findings, and Section 9 concludes with the study's main contributions.

2 Related Works

A systematic literature review revealed (Martins; von Wangenheim, 2023) that only very few courses address the teaching of AI/ML to students from a low SES background, and assess their perceptions of learning and experience. Only two studies, Everson *et al.* (2022) and Zhang *et al*. (2022), focus on students from low-income families, employing different methodologies for teaching AI/ML (Table 1). Everson *et al*. (2022) designed a course aimed at enhancing students' critical analysis of ethics and biases in AI. In contrast, Zhang *et al*. (2022) organized a workshop based on the DAILy curriculum (Lee *et al*., 2021), covering topics from logic systems to advanced concepts like unsupervised algorithms, including Generative Adversarial Networks. The goal of both studies was to improve AI literacy and facilitate discussions on the ethical and societal implications of AI.

Zhang *et al*. (2022) conducted an exploratory case study with 30 middle school students, assessing aspects such as student interest, engagement, and enjoyment. Data were collected through questionnaires, interviews, and observations. Similarly, Everson *et al*. (2022) analyzed engagement and enjoyment in AI/ML learning through questionnaires with 14 high school students. These studies provide insights into students' perceptions of learning and their learning experiences.

Both studies report that students recognize the value of learning AI. The active engagement of students in debates about ethical and social issues related to AI, as shown by Everson *et al*. (2022) and Zhang *et al*. (2022), demonstrates their interest in applying the learned content to broader and more relevant contexts. Zhang *et al*. (2022) noted that students enjoyed the ethics-related activities incorporated into the DAILy curriculum. They reported that students were able to internalize what they experienced, connect with the ethical implications of technology design, and develop positive ideas about their future with AI.

Zhang *et al*. (2022) also observed that students' interest in AI before and after the course remained the same; however, the perceived relevance of AI in students' lives improved slightly. Some students expressed a desire to apply their knowledge of AI and ethics to help their community.

Everson *et al*. (2022) highlighted that some students took pride in their work, sought feedback, and felt their work was worthy of merit. They also reported that a student who presented her ML project was successful and proud, conveying confidence in her learning. However, they emphasized the importance of a stimulating classroom environment and quality instruction for improving student interest and engagement.

Table 1: Main findings of student perception of learning and perception of the learning experience from students from a low SES background.

Reference	Factor(s) evaluated regarding student's perceptions	Data collection method	SES context	Main student's perceptions findings
(Everson *et al.*, 2022)	Interest, Engaging and Enjoying	Questionnaire	• Socioeconomically diverse classroom. • Students who are low-income and/or have no parent or guardian with a bachelor's degree.	• Students were interested and engaged in discussion on topics related to equality, justice, and marginalization in AI.
(Zhang *et al.*, 2022)	Interest, Relevance, Engaging; Enjoying	Questionnaire; Interviews; Observation notes;	• Students from low-income families	• Students continued to find the relevance of AI to their lives after the workshop. • Students have begun considering how AI can impact their lives and future careers. • Most students incorporated ethical and social implications into their views of AI technology after the workshop.

Despite these studies, there is a gap in exploring how a low SES background may affect students' perceptions of learning and learning experiences in AI/ML education. To date, no analyses have been encountered that specifically analyze this effect by comparing the perceptions of students from different SES backgrounds.

Therefore, this research aims to fill this gap by investigating whether students from a low SES background perceive and experience the learning of ML concepts differently compared to their peers from a more general SES background.

3 Research Methodology

This research aims to investigate how a low SES background influences students' perceptions of learning ML concepts and their learning experiences. Specifically, the study conducts a comparative analysis of these perceptions based on the application of an ML course (ML4ALL!) (Martins *et al*., 2023a) among middle and high school students from different SES backgrounds. The focus is particularly on identifying differences between students from low SES and those from a general SES background. To achieve this objective, a quasi-experimental study was conducted, following the guidelines established by UNICEF (2014), comparing the learning perceptions and experiences among students from different SES backgrounds.

Study definition. The Goal/Question/Metric (GQM) approach (Basili *et al*., 1994) was used to systematically derive the research questions and measurements from the study's objective. This methodology provides a structured method for defining measurement criteria, setting clear goals, formulating analysis questions directly linked to these goals, and selecting suitable metrics to assess progress toward these goals. Furthermore, research hypotheses are established based on the research questions.

Data Collection Procedure. The analysis questions and measures are based on the dETECT model (Evaluating TEaching CompuTing) (von Wangenheim *et al*., 2017). This model evaluates the quality of instructional units for teaching computing in schools based on students' perceptions of learning and their learning experience. The dETECT model has demonstrated acceptable reliability (Cronbach's alpha $\alpha = 0.787$) and construct validity, showing a significant degree of correlation among most items in the dETECT measurement instrument (von Wangenheim *et al*., 2017).

The student's perceptions of learning and learning experiences in the ML4ALL! course were analyzed based on the responses to post-course questionnaires based on the dETECT model. Data were collected in the form of feedback, using the post-course questionnaire to gather

students' perceptions of the learning and experience. The responses were collected using Google Forms.

Study Execution. The study involved applying the ML4ALL! course to middle and high school students from different socioeconomic backgrounds. The participants were divided into two groups: those from a low SES background and those from a general SES background (not classified as low SES by specialists), adopting a quasi-experimental research design, as the groups were compared in relation to their perceptions of learning and learning experiences, even though the independent variables were not directly manipulated (UNICEF, 2014).

Data Analysis and Interpretation. The questionnaire responses were documented in spreadsheets and subsequently tabulated, organized, and subjected to a two-level analysis. On the first level, descriptive statistics, including absolute frequencies, were computed to provide a clear comparison of the responses regarding the perceptions of learning and learning experiences of students from a low SES and a general SES background. This stage provided an initial understanding of the data distribution and trends. The second level involved inferential statistics to test the formulated hypotheses. In this study, Pearson's Chi-square test (χ^2) with Yates' continuity correction was applied to assess whether there was a statistically significant difference in the perceptions of students from a low SES background compared to those from a general SES background. The null hypothesis (H_0) posited no difference between the perceptions among students from these backgrounds, while the alternative hypothesis (H_a) suggested a significant difference. The outcome of the Chi-square test, including the p-value and test statistics (χ^2 value), determined the sufficiency of the data to reject H_0 following the methodological guidelines outlined by Lipschutz and Lipson (2011). The results were then analyzed, interpreted, and discussed concluding whether there was a significant difference in the perceptions of learning and learning experiences among students from different SES backgrounds.

This research was approved by the Ethics Committee of the Federal University of Santa Catarina (No. 4.893.560 and No. 5.610.912).

4 Background - ML4ALL! Course and Context

The course "Machine Learning for All!" (ML4ALL!) (Martins *et al*., 2023a) aims to democratize AI/ML knowledge in Brazilian middle and high schools. The course aims to be for all, including low SES students.

4.1 Analysis of the Context

According to recent national and international indicators, Brazil continues to face significant educational challenges, particularly for students from low socioeconomic backgrounds. In 2023, school attendance among children aged 6 to 14 was nearly universal (99.4%), but for those aged 15 to 17, attendance dropped to 91.9% (IBGE, 2024a). School dropout rates increase significantly after age 15, with 9 million young people aged 14–29 not completing high school, and this is more prevalent among Black and Brown students and those from low-income families (IBGE, 2024b).

In terms of learning outcomes, Brazil scored 379 in mathematics, 410 in reading, and 403 in science in the 2022 PISA assessment, placing the country well below the OECD average (472 in math, 476 in reading, 485 in science)(OECD PISA, 2022). Less than half of Brazilian students reach the minimum proficiency in math and science, and Brazil ranks behind most Latin American countries in these areas (Agência Brasil, 2023). The 2023 SAEB and IDEB results also show a decline in student performance across all school stages compared to pre-pandemic levels (Governo Federal, 2024).

Regarding access to educational resources, only 58% of public schools in Brazil have computers and internet access for students, and about 39% of public school students lack any internet-connected device at home (TIC Educação, 2022). These disparities are reflected in the academic performance and digital literacy of students from low SES backgrounds, who often attend under-resourced schools and face additional barriers such as early entry into the labor market, food insecurity, and exposure to violence (IBGE, 2024a).

International benchmarks such as PISA and national indicators (IBGE, SAEB, IDEB) highlight the persistent gap between Brazilian students and their peers in OECD countries, as well as inequalities within Brazil itself (IBGE, 2024a; 2024b; OECD PISA, 2022; OECD PISA, 2018). These contextual factors underscore the importance and urgency of inclusive, equity-oriented educational initiatives in computing and ML for Brazilian youth.

4.2 ML4ALL! Course

In this context, the ML4ALL! course was developed. The course introduces students to the basic concepts of ML, focusing on the task of image classification without the need for prior knowledge in computing, programming, or AI/ML. The learning objectives of the course are aligned with the Brazilian National Curriculum for K-12 education (MEC, 2017), focusing on the "Big Idea 3 - AI, Learning" of the Artificial Intelligence Guidelines K-12 (AI4K12) (Touretzky *et al*., 2019). It incorporates elements of "AI literacy" (Long; Magerko, 2020) and a human-centered ML development process (Amershi *et al*., 2019), as shown in Table 2.

Table 2: Learning objectives of the ML4ALL! course (Martins *et al*., 2023a)

ID	Learning objective
LO1	Know and identify examples of ML application
LO2	Describe basic ML concepts: what a neural network is, how it works, and the ML process
LO3	Collect, clean and label data for the training of an ML model; understand how ML algorithms are influenced by data
LO4	Train an ML model
LO5	Evaluate the performance of an ML model
LO6	Discuss ethical concerns and the impact of ML on society

The ML4ALL! is an interdisciplinary course designed to equip students with both theoretical knowledge and practical application in ML, with a focus on the 'use' stage of the 'Use-Modify-Create' (UMC) cycle (Lee *et al*., 2011). The course guides students through a human-centered ML development process, from data preparation to performance evaluation and prediction (von Wangenheim; von Wangenheim, 2021).

Course content. The ML4ALL!, with a total duration of 8 hours divided into six classes, provides a comprehensive introduction to ML (Martins *et al*., 2023a). The course begins by encouraging students to recognize AI applications in their daily lives, followed by an introduction to the basic concepts of artificial neural networks in the second class. This is illustrated using a 'dog breeds' image classification scenario. In subsequent classes, students are guided through the development of an ML model for classifying recyclable trash images, a task aligned with the UN's Sustainable Development Goals (United Nations, 2015). This process includes the preparation of the dataset, model training, performance assessment through established metrics, and prediction of new images (von Wangenheim; von Wangenheim, 2021). The course concludes with a review of the ML development process, stimulating a reflection and critical discussion on ethical issues and the societal impact of ML, as well as a demonstration of ML career opportunities (Martins *et al*., 2023a).

Pedagogical approaches. The ML4ALL! course adopts active and problem-based learning strategies to assist students in building their understanding and engaging them in higher-order thinking tasks that address real-world problems (Martins *et al*., 2023a). The course minimizes the duration of lecture-based moments, favoring a variety of instructional methods to maintain an effective and engaging learning environment. These methods include videos, interactive slides, demonstrations, and hands-on activities (Martins *et al*., 2023a).

To ensure accessibility in Brazilian schools, all course materials are provided in Brazilian Portuguese, the native language of students at this educational stage in Brazil. The instructional material is freely available at the course website (https://cursos.computacaonaescola.ufsc.br/cursos/curso-mlparatodos).

Technological tools. The course uses a variety of technological tools to facilitate the teaching and learning process. These include interactive and online applications such as 'Quick Draw!' (Google A.I. Experiment, 2022) and the 'Object Detector and Classifier - TensorFlow App' (Hash Bits, 2018), which allows students to experience the potential of AI/ML. The 'MIT Moral Machine' (MIT, 2017) is also used to provide insights into human experience in moral decisions made by AI, such as autonomous cars, and to stimulate discussions related to AI ethics. The Google Teachable Machine (Google, 2023) is a key tool used in the course. This free and online visual platform enables the training of ML models without the need for prior coding knowledge. It provides support for initial model evaluation and performance testing and is available in Brazilian Portuguese, making it well-suited for Brazilian schools. Students can export the trained ML model in ".tm" format, creating an artifact essential for the subsequent automatic assessment and feedback of their learning using CodeMaster ML tool[1], which offers a playful representation of the total score (Rauber et al., 2023).

The course application is supported by the Moodle platform hosted at the university, which provides the instructional materials. Students who are not directly affiliated with the university create an external account to gain access. Some examples of the materials and tools used in the course are shown in Figure 1.

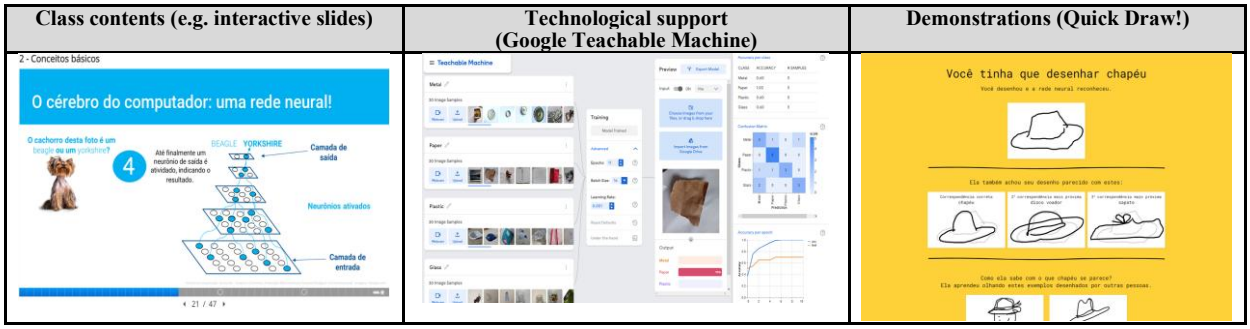


Figure 1: Examples of material and tools used in the ML4ALL! course (Martins *et al*., 2023a).

Feedback on students' perception of learning and perception of learning experience. In the course, students respond to a post-course questionnaire to assess their perception of learning and the learning experience.

Students' perception of their learning refers to how students assess their own understanding and ability to apply the main concepts taught in the course. In this study, this perception was measured with questions such as "I understand what ML is," "I can develop an

[1]CodeMaster ML Tool: http://apps.computacaonaescola.ufsc.br/codemaster/

ML model for image classification," "Developing an ML model is easy/not easy," and "I can explain to a friend what ML is."

Learning experience relates to students' overall feelings and attitudes toward the course, including enjoyment, motivation, and satisfaction. This was assessed with items such as "The course was easy/not easy," "The course was fun/not fun," "Class time has passed quickly/not quickly," "I want to learn more about ML," and "Overall the course was excellent/not excellent."

While perception of learning focuses on students' confidence and mastery of content, learning experience covers affective and motivational aspects of the educational process.

This questionnaire is based on the dETECT model (von Wangenheim *et al.*, 2017), including items that measure various quality factors of the student's perception of learning and experiences, such as self-confidence, enjoyability, and the overall quality of the course (Table 3).

Table 3: Feedback questionnaire based on the dETECT model (von Wangenheim *et al*., 2017).

Feedback	Quality factor	Questionnaire items	Response scale
Student's perception of learning	Learning/Self-confidence	I understand what ML is	Yes, no
		I can develop an ML model for image classification	Yes, no
		Developing an ML model is?	5-point ordinal scale (Very easy/Easy/Average/Difficult/Very Difficult)
		I can explain to a friend what ML is	Yes, no
Perception of student learning experience	Enjoyability	The course was?	5-point ordinal scale (Lot of fun/Fun/Average/Annoying/Very Annoying)
		The course was?	5-point ordinal scale (Very easy/Easy/Average/Difficult/Very Difficult)
		Class time has passed?	5-point ordinal scale (Very Quickly/Quickly/Average/Slowly/Very Slowly)
		I want to learn more about ML	Yes, no
	Overall quality of the course	Overall the course was?	5-point ordinal scale (Excellent/Good/Regular/Bad)

Instructional modes. The course can be conducted as face-to-face classes, remote online courses with instructors, remote self-paced learning, or in a hybrid format (with remote and in-person instructors). It can be applied as an extracurricular activity, within the school curriculum, or in an interdisciplinary way as part of science classes (Martins *et al.*, 2023a).

5 Course Applications

In 2021 to 2022, the ML4ALL! course was applied to 266 middle and high school students, aged 14-18, from different SES backgrounds (Table 4). In this research, the students were categorized based on their SES context, either as those from a low SES background or a general SES background (those not recognized as low SES background by specialists) (Figure 2).

Course applications with students from a general SES background. The course has been applied in five cases (1-5) with students from a general SES background involving 108 students from diverse SES backgrounds, excluding those from a low SES (Martins *et al*., 2023a). These course applications differed in instructional methods and types. Most were extracurricular activities accessible to anyone interested with a computer and internet at home. Course applications 2-4 were applied online via Google Meet, guided by two instructors and ML experts

who provided brief online lectures. Students then completed individual hands-on tasks, with instructors available online for support. This approach balanced guided teaching with the independent exploration of tasks. The first application of course, was an exception, conducted as part of regular school classes in a computer lab, with ML experts present both in-person and online via Google Meet, and the regular classroom teacher assisting. The fifth application of the course was designed for autonomous, self-paced learning without an instructor, freely available to anyone interested through the "Computação na Escola/UFSC" initiative's website.

Course application with students from a low SES background. The sixth application of the course applied with students from a low SES background, was an extracurricular activity involving 158 middle and high school students, who's background has been confirmed by specialists of Vilson Groh Institute (Martins *et al*., 2023b; IVG, 2022). This application was part of the PodeCrer Program at the Vilson Groh Institute, aimed at empowering students from marginalized communities facing various challenges, such as difficult family conditions and living in high-crime neighborhoods (IVG, 2022). The program's goal is to align educational opportunities with broader social justice objectives, like fighting poverty and violence, by promoting leadership, creativity, and technological skills. It also aims to bring students closer to the innovation and technology ecosystem to improve their career and educational opportunities. The program provides comprehensive support for students, including pedagogical, social, and psychological support, daily meals, scholarships, and transportation vouchers (IVG, 2022).

The course took place in the Vilson Groh Institute's computer lab, where eight weekly sessions of two hours each were held from September to November 2022. Each session accommodated 25 students in the lab, equipping students individually with a laptop and headphones.

The course was applied in a hybrid format, with an ML expert providing instruction remotely via Google Meet. This included lectures, discussions, and hands-on activity guidance. Simultaneously, other ML specialists were present in person to offer individual support. Additional instructional support was complemented by former students of the ML4ALL! course, who also came from low SES backgrounds, enrolled in the PodeCrer program/Vilson Groh Institute, and who acted as peer tutors.

Table 4: Overview of the course applications.

Applications for SES background	Date	Applications (#) in institutions	Instruction mode	Instruction type	Age (years)	Educational stage	No. of students
General SES background	2021-2022	#1: Public Middle School; #2-4: Open to any interested student organized by the Computação na Escola/UFSC e IVG #5: Remotely via the site.	Hybrid and Remote	As part of school classes and extracurricular	14-18	Middle and High school	108
Low SES background	2021-2022	#6: Non-profit educational organization for low SES background students Computação na Escola/UFSC e IVG	Hybrid	extracurricular	14-18	Middle and High school	158
Total							**266**

Demographic of the course applications. The majority of the students from a general SES background were male, native Brazilians from various schools with differing levels of teaching quality and infrastructure. They exhibited varying computing skills, and most had access to computers at home (Martins *et al*., 2023a).

In contrast, students from the low SES background had a more balanced distribution of 'sex assigned at birth'. Most of these students were native Brazilians, accompanied by a few immigrants proficient in Brazilian Portuguese. These students face various socioeconomic

challenges, including being part of refugee families, family conflicts, food insecurity, and living in high-crime communities. Most did not have home access to a computer and primarily gained exposure to computing through the PodeCrer program at the Vilson Groh Institute. Additionally, the schools attended by these students from a low SES background often suffer from low teaching quality and a lack of teacher training in computing (Martins *et al.*, 2023b; IVG, 2022).

The majority of students from both groups (low SES and general SES background) were over 15 years old and enrolled in high school. Despite their different SES backgrounds, all students demonstrate a basic understanding of languages, mathematics, and natural sciences in conformity with Brazil's Common National Curriculum (MEC, 2017). They also displayed skills in critical thinking, problem-solving, and ethical decision-making (Martins *et al*., 2023a; 2023b; IVG, 2022). A summary of the demographic of the course applications is presented in Table 5.

Table 5: Overview of the demographic of the course applications.

SES background	**Sex assigned at birth***		**Educational stage**	
	Female	**Male**	**Middle school (≤ 15 y)**	**High school (>15 y)**
General SES background	36 (35.6%)*	65 (64.4%)*	31 (28.7%)	77 (71.2%)
Low SES background	77 (48.7%)	81 (51.3%)	63 (39.8%)	95 (60.2%)
Total	113	146	94	172

*Some students did not report the sex assigned at birth.

All participants gave their consent to take part and voluntarily shared their learning outcomes and feedback during the course.

6 Evaluation of the Course Applications

This section presents the definition of the evaluation and the date collection of the course applications.

6.1 Definition of the Evaluation

The objective of this study is to compare the perception of learning and learning experiences of middle and high school students from a low SES background to those from a general SES background. This comparison is conducted through a series of applications of the ML4ALL! course. Consequently, the following analysis questions and hypotheses have been derived:

AQ1. Student Perception of Learning: Does student perception of learning differ between those from a low SES background and those from a general SES background? Do educational stages and sex assigned at birth potentially moderate this relationship?

- H_{01}. There are no significant differences in the perception of learning between students from a low SES and a general SES background. Furthermore, the educational stage and sex assigned at birth do not significantly moderate this perception.
- H_{a1}. There are significant differences in the perception of learning between students from a low SES and a general SES background. Additionally, the educational stage and sex assigned at birth significantly moderate this perception.

AQ2. Student Perception of Learning Experience: Does the perception of the learning experience differ between students from a low SES background and those from a general SES background? Do educational stages and sex assigned at birth potentially moderate this relationship?

- H_{02}. There are no significant differences in the perception of the learning experience between students from a low SES and a general SES background. Furthermore, the educational stage and sex assigned at birth do not significantly moderate this perception.
- H_{a2}. There are significant differences in the perception of the learning experience between students from a low SES and a general SES background. Additionally, the educational stage and sex assigned at birth significantly moderate this perception.

6.2 Data Collection

Data was collected from students during the applications of the ML4ALL! course, using a post-course questionnaire based on the dETECT model (von Wangenheim *et al*., 2017). This questionnaire was designed to gather feedback on students' perceptions on learning and their experience. Data was collected from 215 students, representing 80% of the course participants. The remaining students did not respond to the post-course questionnaire due to their absence during the administration of the questionnaire or chose to utilize the time to refine their ML models. For subsequent analysis and comparison, the responses were categorized based on different factors: SES background (low SES and general SES background), sex assigned at birth (female and male), and educational stage (middle and high school). The quantities of collected data are summarized in Table 6.

Table 6: Overview on the collected data.

SES background	**Questionnaire(n)**				
	All students	Female	Male	Middle School	High School
General SES background	93	29	53	28	64
Low SES background	122	66	56	46	76

7 Results of the Evaluation

This section presents an empirical analysis to explore the influence of the SES background on students' perceptions of learning and the learning experience in the ML4ALL! course, and also examining the possible moderating effects of SES background in sex assigned at birth and educational stage. For each research question (AQ1 and AQ2), a set of null (H_0) and alternative hypotheses (H_a) is tested using statistical methods.

7.1 Does student perception of learning differ between those from a low SES background and those from a general SES background?

The analysis of the questionnaire responses using Pearson's Chi-squared test with Yates' continuity correction yielded mixed results regarding the perception of learning in the context of the ML4ALL! course among students from different socioeconomic backgrounds (Table 7). The significant differences in students' understanding of "what ML is" ($\chi^2(1) = 7.47$, $p = .006$) and their ability to "explain ML to a friend" ($\chi^2(1) = 19.35$, $p < .001$) led to the rejection of the null hypothesis (H_{01}), which stated that there would be no significant differences in learning perceptions between the two groups. These findings support the alternative hypothesis (H_{a1}) that posits significant differences in these aspects of learning perception. Conversely, the lack of significant differences in students' perceptions of their ability to "develop an ML model" ($\chi^2(1) = 0.03$, $p = .86$) and the perceived difficulty of "developing an ML model" ($\chi^2(1) = 2.27$, $p = .13$) means that the null hypothesis (H_{01}) cannot be rejected in these areas. Therefore, the study does not provide evidence to support the alternative hypothesis (H_{a1}) regarding these particular perceptions of learning (Fig. 3).

Table 7: Response frequency and statistical analysis of the perception of learning of all students from a general and a low SES background.

Questionnaire item	Frequencies of students' responses	Test Statistic*	p-value**
I understand what ML is ■ Yes ■ No	All General: 90 / 3 All Low SES: 103 / 19	$\chi^2 = 7.467$	$p = 0.0062$
I can develop an ML model for image classification ■ Yes ■ No	All General: 83 / 10 All Low SES: 110 / 11	$\chi^2 = 0.030$	$p = 0.8624$
Developing an ML model is ■ Easy ■ Not easy	All General: 35 / 58 All Low SES: 33 / 89	$\chi^2 = 2.2668$	$p = 0.1322$
I can explain to a friend what ML is ■ Yes ■ No	All General: 84 / 9 All Low SES: 77 / 45	$\chi^2 = 19.349$	$p < 0.001$

*degree of freedom of χ^2 test = 1. / **extremely small χ^2 value and p-value, summarized representation at < 0.001.

In summary, the findings indicate that the SES background may influence students' conceptual understanding and ability to explain ML. At the same time, it does not appear to affect their perceptions of practical skills in developing ML models or the difficulty of such tasks.

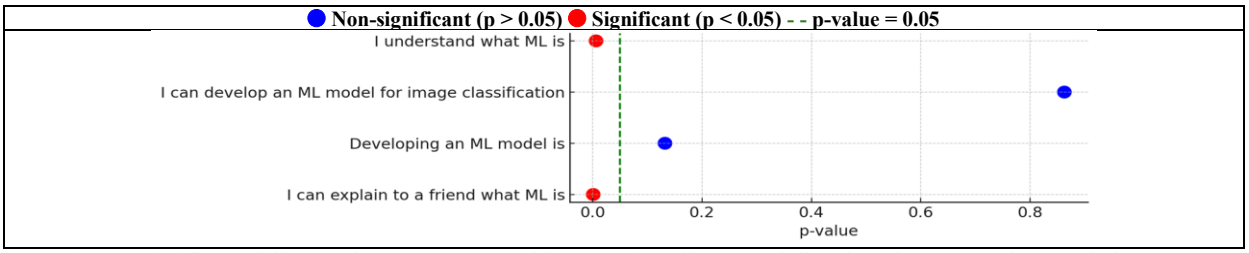


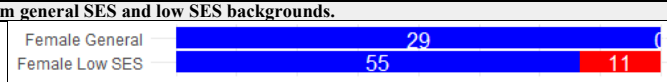
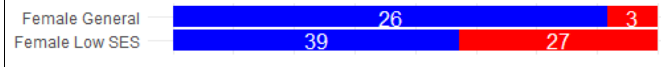
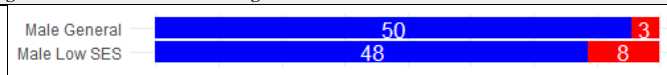
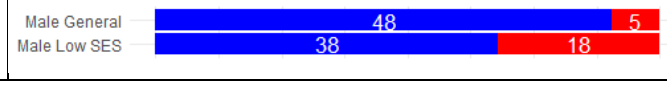
Figure 3: Significance differences between responses of the perception of learning of all students from a general SES and a low SES background.

7.1.1 Are there differences in student perception of learning by sex assigned at birth comparing students from a low SES background versus a general SES background?

The Chi-square test results indicate that for female students, there are statistically significant differences in understanding "what ML is" and in their ability to explain it to a friend, with Chi-square values of ($\chi^2(1) = 3.96$, $p = .047$) and ($\chi^2(1) = 7.35$, $p = .007$) respectively (Table 8). These results lead to rejecting the null hypothesis (H_{01}) for these aspects of learning perception, supporting the alternative hypothesis (H_{a1}) that there are significant differences. For male students, a significant difference was observed only in their ability to explain "what ML is" to a friend, with a Chi-square value of ($\chi^2(1) = 7.13$, $p = .008$), also leading to the rejection of the null hypothesis (H_{01}) for this aspect and supporting the alternative hypothesis (H_{a1}).

However, no significant differences were found for both female and male students in their perception of their ability to develop an ML model or in the perception of the difficulty of this task, with chi-square values indicating non-significance ($p = 1.00$ and $p = .80$) for females, and ($p = .94$ and $p = .41$) for males. These findings indicate a failure to reject the null hypothesis (H_{01}) for these aspects, suggesting that sex assigned at birth does not significantly moderate this perception.

Table 8: Response frequency and statistical analysis of the perception of learning of female and male students from a general and a low SES background.

Questionnaire items	Frequencies of students' responses	Test Statistic*	p-value**
Responses of female students from general SES and low SES backgrounds.			
I understand what ML is ■ Yes ■ No		$\chi^2 = 3.959$	$p = 0.0466$
I can develop an ML model for image classification ■ Yes ■ No		$\chi^2 < 0.001$	$p = 1$
Developing an ML model is ■ Easy ■ Not easy		$\chi^2 = 0.0620$	$p = 0.8033$
I can explain to a friend what ML is ■ Yes ■ No		$\chi^2 = 7.3537$	$p = 0.006$
Responses of male students from general SES and low SES backgrounds.			
I understand what ML is ■ Yes ■ No		$\chi^2 = 1.3832$	$p = 0.2396$
I can develop an ML model for image classification ■ Yes ■ No		$\chi^2 = 0.00507$	$p = 0.9432$
Developing an ML model is ■ Easy ■ Not easy		$\chi^2 = 0.66467$	$p = 0.4149$
I can explain to a friend what ML is ■ Yes ■ No		$\chi^2 = 7.1256$	$p = 0.0075$

*degree of freedom of χ^2 test = 1. / **extremely small χ^2 value and p-value, summarized representation at < 0.001.

In this comparison, the alternative hypothesis (H_{a1}) is supported for the aspects of understanding and explaining ML concepts, where significant differences were found. However, the null hypothesis (H_{01}) is not rejected for the perceptions related to the ability to develop an ML model and the difficulty of the task, indicating no significant differences between the SES groups in these respects (Fig. 4).

7.1.2 Are there differences in student perception of learning by educational stage comparing students from a low SES background versus a general SES background?

Based on the results and the research question regarding differences in student perception of learning by educational stage (Table 9). The Chi-square test results indicate that for middle school students, there are statistically significant differences in their perception of the ease of developing an ML model and their ability to explain 'what ML is' to a friend, with Chi-square values of ($\chi^2(1) = 4.79$, $p = .03$) and ($\chi^2(1) = 11.36$, $p < .001$) respectively. These results lead to rejecting the null hypothesis (H_{01}) for these aspects of learning perception, supporting the alternative hypothesis (H_{a1}) that there are significant differences and that the educational stage potentially moderates this relationship.

For high school students, statistically significant differences were also identified in their perception of the ease of developing an ML model and their ability to explain 'what ML is' to a friend, with Chi-square values of ($\chi^2(1) = 12.67$, $p < .001$) and ($\chi^2(1) = 8.00$, $p < .001$) respectively. This also leads to rejecting the null hypothesis (H_{01}) for these aspects and supports the alternative hypothesis (H_{a1}).

However, no significant differences were found for both middle and also high school students in their understanding of 'what ML is' and the perceived ability to 'develop an ML model', with Chi-square values indicating non-significance. These findings indicate a failure to reject the

null hypothesis (H_{01}) for these aspects, suggesting that educational stages do not significantly moderate this perception.

Table 9: Response frequency and statistical analysis of the perception of learning of middle and high school students from a general and a low SES background.

Questionnaire items	Frequencies of students' responses	Test Statistic*	p-value**
Responses of middle school students from general SES and low SES backgrounds.			
I understand what ML is ■ Yes ■ No	Middle School General: 27 / 1 Middle School Low SES: 36 / 10	$\chi^2 = 3.2175$	$p = 0.0728$
I can develop an ML model for image classification ■ Yes ■ No	Middle School General: 25 / 3 Middle School Low SES: 39 / 7	$\chi^2 = 0.0395$	$p = 0.8423$
Developing an ML model is ■ Easy ■ Not easy	Middle School General: 13 / 15 Middle School Low SES: 9 / 37	$\chi^2 = 4.7952$	$p = 0.0285$
I can explain to a friend what ML is ■ Yes ■ No	Middle School General: 26 / 2 Middle School Low SES: 24 / 22	$\chi^2 = 11.355$	$p < 0.001$
Responses of high school students from general SES and low SES backgrounds.			
I understand what ML is ■ Yes ■ No	High School General: 62 / 2 High School Low SES: 67 / 9	$\chi^2 = 2.5419$	$p = 0.1109$
I can develop an ML model for image classification ■ Yes ■ No	High School General: 57 / 7 High School Low SES: 71 / 4	$\chi^2 = 0.8185$	$p = 0.3656$
Developing an ML model is ■ Easy ■ Not easy	High School General: 21 / 8 High School Low SES: 24 / 52	$\chi^2 = 12.673$	$p < 0.001$
I can explain to a friend what ML is ■ Yes ■ No	High School General: 58 / 6 High School Low SES: 53 / 23	$\chi^2 = 8.0019$	$p < 0.001$

*degree of freedom of χ^2 test = 1. / **extremely small χ^2 value and p-value, summarized representation at < 0.001.

The analysis results show that the alternative hypothesis (H_{a1}) is supported for the aspects of understanding and explaining ML concepts, where significant differences were found. However, the null hypothesis (H_{01}) is not rejected for the perceptions related to the ability to develop an ML model and the difficulty of the task, indicating no significant differences between the groups in these respects (Fig 5).

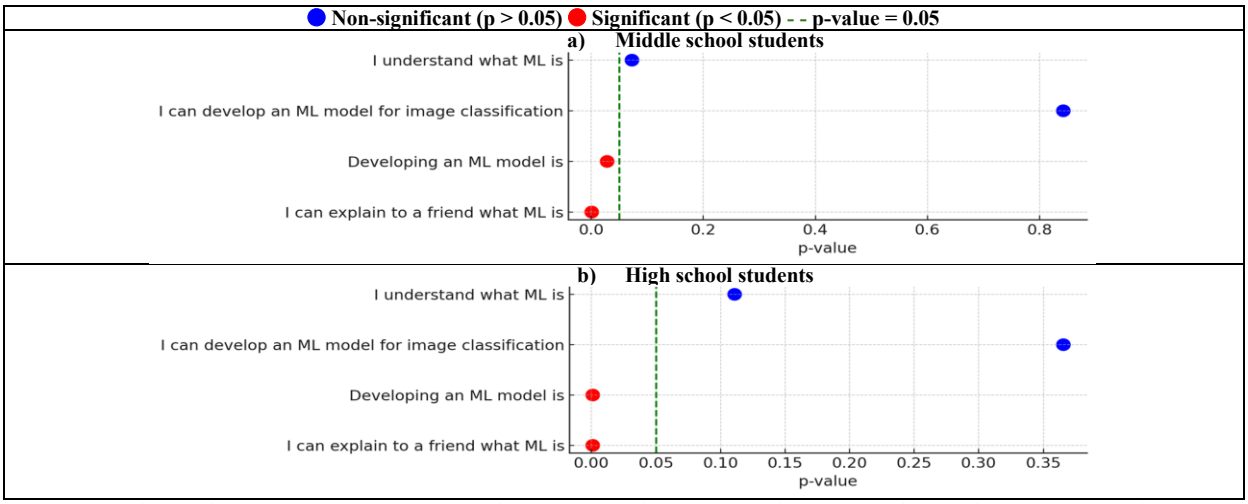


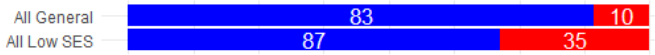
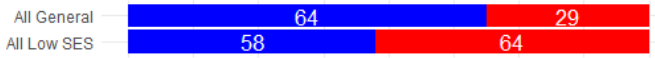
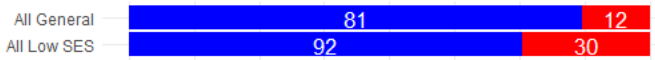
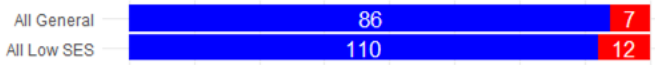
Figure 5: Significance differences between responses of the perception of learning of middle and high school students from a general SES and a low SES background.

7.2 Does the perception of the learning experience differ between students from a low SES background and those from a general SES background?

The analysis of the student's responses to the questionnaire items reveals differences in the perception of the learning experience between students from a general SES and a low SES background (Table 10). Three out of five aspects of the learning experience showed significant differences between the two groups. Specifically, course enjoyment ($\chi^2(1) = 9.20$, $p = 0.0024$), the perception of class time passing quickly ($\chi^2(1) = 8.89$, $p = 0.0028$), and the desire to learn more about ML ($\chi^2(1) = 3.87$, $p = 0.0490$) varied significantly between the two groups. These findings suggest that students' enjoyment of the course, their perception of the passage of class time, and their continued interest in ML might be influenced by their SES background.

However, the perceived difficulty of the course and the overall course evaluation did not show significant differences between the two groups. These aspects seem to be perceived consistently across students, regardless of their SES context.

Table 10: Response frequency and statistical analysis of the perception of the learning experience of all students from a general and a low SES background.

Questionnaire items	Frequencies of students' responses	Test Statistic*	p-value**
The course was? ■ Easy ■ Not easy		$\chi^2 = 1.0100$	$p = 0.3150$
The course was? ■ Fun ■ Not fun		$\chi^2 = 9.202$	$p = 0.0024$
Class time has passed? ■ Quickly ■ Not quickly		$\chi^2 = 8.885$	$p = 0.0028$
I want to learn more about ML ■ Yes ■ No		$\chi^2 = 3.8721$	p = 0.0490
Overall the course was? ■ Excellent ■ Not Excellent		$\chi^2 = 0.1214$	$p = 0.7275$

*degree of freedom of χ^2 test = 1. / **extremely small χ^2 value and p-value, summarized representation at < 0.001.

Based on these findings, the null hypothesis (H_{02}) that there are no significant differences in the perception of the learning experience between students from a general SES and a low SES background is rejected for the aspects of course enjoyment, perception of class time, and interest in ML. This supports the alternative hypothesis (H_{a2}) that there are significant differences in the perception of the learning experience between these groups in these aspects. Conversely, for the aspects of the perceived difficulty of the course and overall course evaluation, the null hypothesis (H_{02}) is not rejected. This indicates that the perception of these aspects does not significantly differ between the two groups, suggesting that these aspects of the learning experience are perceived similarly by students regardless of their SES background (Fig 6).

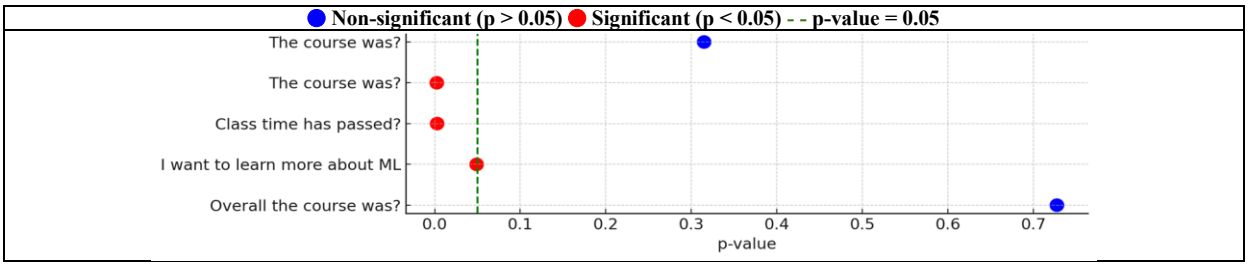


Figure 6: Significance differences between responses of the perception of the learning experience of all students from a general SES and a low SES background.

7.2.1 Are there differences in student perception of learning experience by sex assigned at birth comparing students from a low SES background versus a general SES background?

When comparing the responses of female and also male students from both a low and a general SES background regarding their perceptions of the learning experience, significant differences were observed in specific areas (Table 11). For female students, the enjoyment of the course and the perception of how quickly class time passed, with *p*-values of 0.0259 and 0.008, respectively. These findings suggest that female students' enjoyment and temporal perception of the course may be influenced by their SES context. In contrast, no significant differences were detected in the perceived difficulty of the course, its overall evaluation, or the desire to learn more about ML, implying a uniform perception across female students from different SES backgrounds.

For male students, the analysis showed no statistically significant differences in any of the measured aspects of the learning experience, indicating a consistent perception across SES backgrounds.

Table 11: Response frequency and statistical analysis of the perception of the learning experience of female and male students from a general and a low SES background.

Questionnaire items	Frequencies of students' responses	Test Statistic*	p-value**
Responses of female students from general SES and low SES backgrounds.			
The course was? ■ Easy ■ Not easy	Female General 10 19 Female Low SES 28 38	χ^2 = 0.25024	p = 0.6169
The course was? ■ Fun ■ Not fun	Female General 27 2 Female Low SES 46 20	χ^2 =the 4.9573	p = 0.0259
Class time has passed? ■ Quickly ■ Not quickly	Female General 24 5 Female Low SES 34 32	χ^2 =7.0092	p = 0.008
I want to learn more about ML ■ Yes ■ No	Female General 26 3 Female Low SES 47 19	χ^2 =2.8844	p =0.0894
Overall the course was? ■ Excellent ■ Not Excellent	Female General 27 2 Female Low SES 59 7	χ^2 =0.03541	p = 0.8507
Responses of male students from general SES and low SES background.			
The course was? ■ Easy ■ Not easy	Male General 35 18 Male Low SES 28 28	χ^2 = 2.251	p = 0.1335
The course was? ■ Fun ■ Not fun	Male General 46 7 Male Low SES 41 15	χ^2 = 2.3304	p = 0.126
Class time has passed? ■ Quickly ■ Not quickly	Male General 30 23 Male Low SES 24 32	χ^2 = 1.5452	p =0.2138
I want to learn more about ML ■ Yes ■ No	Male General 44 9 Male Low SES 45 11	χ^2 =0.0123	p = 0.911
Overall the course was? ■ Excellent ■ Not Excellent	Male General 48 5 Male Low SES 51 5	χ^2 =0.000	p = 1

*degree of freedom of χ^2 test = 1. / **extremely small χ^2 value and p-value, summarized representation at < 0.001.

Consequently, the null hypothesis (H_{02}), which posited no significant differences in the perception of the learning experience between students from a low and a general SES background, is rejected for female students regarding course enjoyment and the perception of class time. This supports the alternative hypothesis (H_{a2}) for these aspects of the learning experience. On the other hand, for male students, the null hypothesis (H_{02}) is maintained, as the data did not reveal any significant differences in their perception of the learning experience (Fig 7).

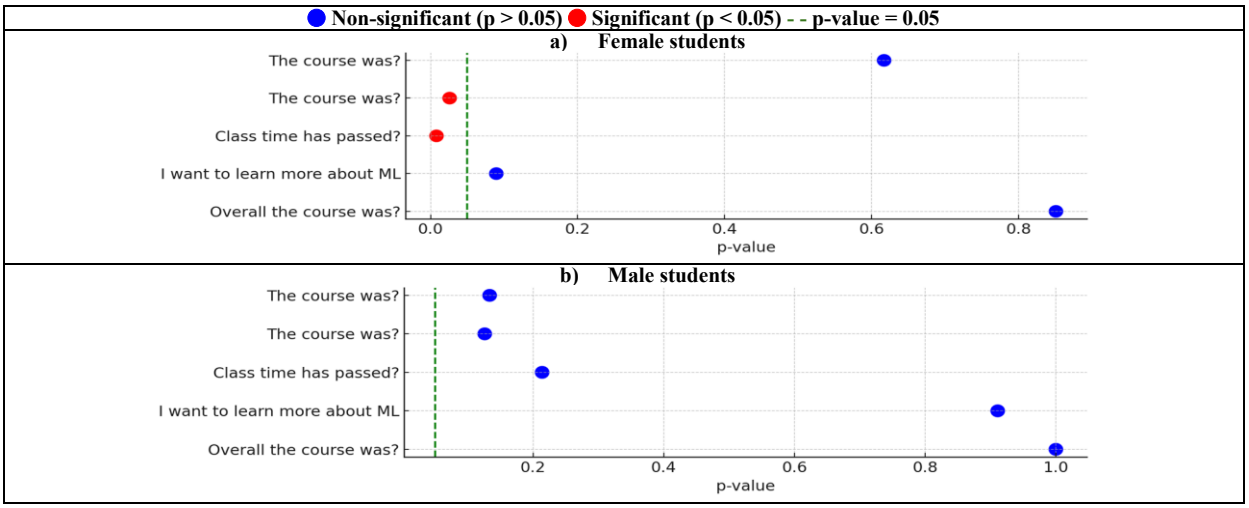


Figure 7. Significance differences between responses of the perception of the learning experience of female and male students from a general and a low SES background.

7.2.2 Are there differences in student perception of learning experience by educational stage comparing students from a low SES background versus a general SES background?

The responses of middle school and also high school students from a low and a general SES background regarding their perceptions of the learning experience are shown in Table 12 and Figure 8. The analysis of the responses from middle school students revealed no statistically significant differences in their perceptions of the learning experience, regardless of their SES background.

In contrast, the analysis of the responses from high school students revealed statistically significant differences in two items. Specifically, there were significant differences in the perception of whether the course was fun ($\chi^2(1) = 5.87$, $p = 0.0153$) and whether class time passed quickly ($\chi^2(1) = 3.84$, $p = 0.0499$) between students from a low and a general SES background.

However, for the remaining items, including the perceived ease of the course, the desire to learn more about ML, and the overall evaluation of the course, no significant differences were found. Therefore, for these items, the null hypothesis (H_{02}) cannot be rejected, indicating that these aspects of the learning experience are consistent, regardless of SES background.

Table 12: Response frequency and statistical analysis of the perception of the learning experience of middle and high school students from a general and a low SES background.

Questionnaire items	Frequencies of students' responses	Test Statistic*	p-value**
Responses of middle school students from general SES and low SES backgrounds.			
The course was? ■ Easy ■ Not easy	Middle School General: 15, 13 / Middle School Low SES: 17, 29	χ^2 = 1.3393	p = 0.2472
The course was? ■ Fun ■ Not fun	Middle School General: 22, 6 / Middle School Low SES: 28, 18	χ^2 =1.7466	p = 0.1863
Class time has passed? ■ Quickly ■ Not quickly	Middle School General: 18, 10 / Middle School Low SES: 18, 28	χ^2 =3.4593	p =0.0629
I want to learn more about ML ■ Yes ■ No	Middle School General: 24, 4 / Middle School Low SES: 31, 15	χ^2 =2.1772	p = 0.1401
Overall the course was? ■ Excellent ■ Not Excellent	Middle School General: 26, 2 / Middle School Low SES: 41, 5	χ^2 =0.0148	p =0.9031
Responses of high school students from general SES and low SES backgrounds.			
The course was? ■ Easy ■ Not easy	High School General: 34, 30 / High School Low SES: 39, 37	χ^2 = 0.0019	p = 0.965
The course was? ■ Fun ■ Not fun	High School General: 60, 4 / High School Low SES: 59, 17	χ^2 =5.871	p = 0.0153
Class time has passed? ■ Quickly ■ Not quickly	High School General: 45, 19 / High School Low SES: 40, 36	χ^2 =3.8424	p =0.0499
I want to learn more about ML ■ Yes ■ No	High School General: 56, 8 / High School Low SES: 61, 15	χ^2 = 0.8505	p =0.356
Overall the course was? ■ Excellent ■ Not Excellent	High School General: 59, 5 / High School Low SES: 69, 7	χ^2 = 0.00	p = 1

*degree of freedom of χ^2 test = 1. / **extremely small χ^2 value and p-value, summarized representation at < 0.001.

The findings suggest that while some aspects of the learning experience do not differ significantly between students from different SES backgrounds, others do for high school students, and these differences suggest there are some moderating by the educational stage.

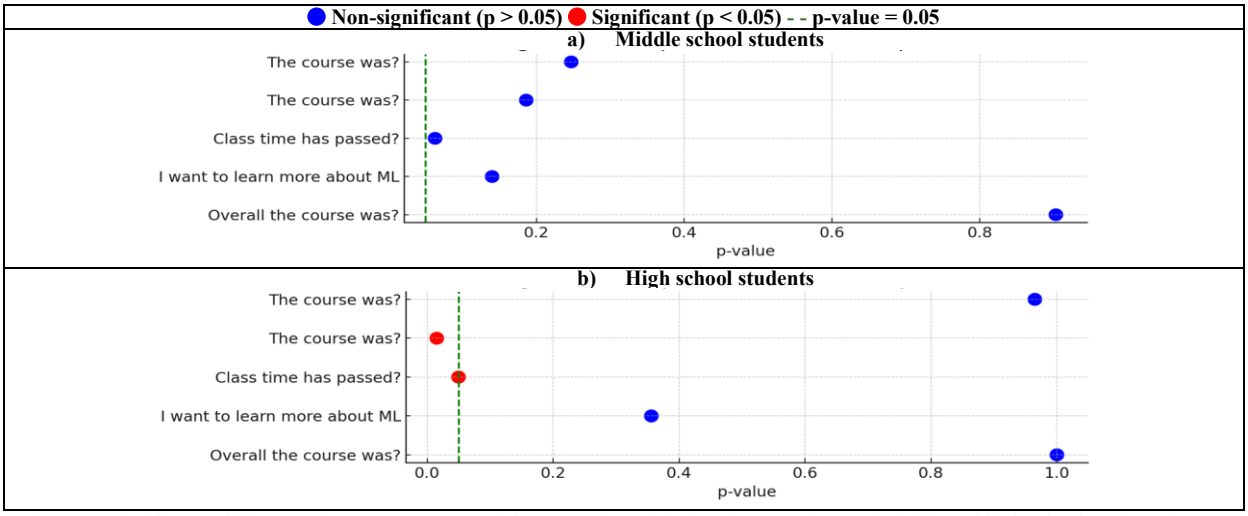


Figure 8: Significance differences between responses of the perception of the learning experience of middle and high school students from a general and a low SES background.

This underscores the importance of considering both SES backgrounds and educational stages in designing and implementing effective ML teaching strategies.

7.3 Threats to validity

Some aspects of the study design could potentially influence the validity of the findings. A primary concern is the potential for low statistical power due to the limited sample size. However, the sample size of 266 students is assumed to be adequate for the analyses conducted. The conclusion validity of the findings is strengthened by the reliability of the measurements used for data collection, including the dETECT instrument with acceptable reliability with the data collected in this study (Cronbach's alpha $\alpha = 0.77$ and Omega McDonalds = 0.83).

Regarding internal validity, a low dropout rate was noted, 11.2% in the group from a low SES background and 9.2% in the group from a general SES background. Given the diversity of SES backgrounds among the study participants, it is assumed that this dropout rate did not significantly influence the results.

However, it is important to emphasize that the observed differences in student perceptions based on SES background are primarily descriptive, derived from the collected data, and should not be interpreted as causal inferences. And, although variations in learning and learning experience perceptions among students from different SES backgrounds were observed, attributing these differences directly to the SES context is complex due to the potential influence of uncontrolled factors on the results. For example, disparities in education quality, resource accessibility, or prior programming experience may also have contributed to the observed differences. These factors might be unevenly distributed among the general and low SES groups, potentially driving the observed association.

Regarding the generalizability of the results, it is essential to consider that the findings presented here are based on data collected from the application of the ML4ALL! course in Brazil. Therefore, the potential for generalizing these results may be limited. However, given the scarcity of findings in the literature on teaching ML to low SES students, these results are considered as a valuable initial contribution. Further research is necessary to confirm these findings and deepen the understanding of the variables influencing perceptions of learning and perceived learning experience of AI/ML in different socioeconomic contexts.

8 Discussion

This study aimed to compare the perception of learning and learning experiences of middle and high school students from a low and a general SES background in the context of the ML4ALL! course. The results revealed some significant differences in aspects of the perception of the learning and learning experience, with certain moderations according to factors such as low SES background, sex assigned at birth, and educational stage.

The study's findings about students' perception of learning indicate that the SES background may influence students' conceptual understanding and ability to explain ML. Specifically, significant differences were observed in students' understanding of "what ML is" and their ability to "explain ML to a friend" between the two groups from different SES backgrounds. These results are significant, as they suggest that students from a low SES background may face challenges in understanding complex concepts, such as ML, which could be attributed to various factors such as lack of access to resources, and/or less prior exposure to technology, corroborating the findings presented by Martins and von Wangenheim *et al*., (2023) and Martins *et al*. (2023b).

However, the study did not find significant differences in students' perceptions of their ability to "develop an ML model" or the perceived difficulty of developing an ML model. This suggests that once students engage with practical tasks, their confidence and perception of difficulty may align, regardless of their SES background. This finding is encouraging, as it implies that practical experience in ML can potentially promote satisfactory perceptions of learning among students from different SES backgrounds. It also may be an indication that the Google Teachable Machine is an adequate tool to teach a basic understanding of the application of ML across different backgrounds.

Analyzing the perception of the learning experience revealed significant differences in course enjoyment, the perception of class time passing quickly, and the desire to learn more about ML between the two groups from different backgrounds. These findings suggest that students' enjoyment of the course and their engagement with the material may be influenced by their SES background.

From these results, it is possible that students from a low SES context, due to facing additional stressors, are affected in their satisfaction and perception of class time. These stressors for students from a low SES background, as observed by the instructors in the course and in other studies (Martins *et al*., 2023b; Martins; von Wangenheim, 2023; Destin *et al*., 2019), may be linked to their family situations, logistical issues (e.g., public transportation), and low self-confidence (e.g., due to the lack of contact with computers).

Interestingly, the perceived difficulty of the course and the overall course evaluation did not show significant differences between the two groups. This indicates that students from different SES backgrounds may perceive the challenge and value of the course similarly. This similarity in perceptions of the learning experience is an indication that the ML4ALL! course may have effectively provided equal conditions for the students in terms of the content and complexity of the course.

Based on the results of the study, it was found that both factors "sex assigned at birth" and "educational stage" have some significantly moderating the perception of learning and learning experiences among students from different SES backgrounds. In terms of "sex assigned at birth", significant differences were found regarding the perception of "understanding of ML concepts" and the ability to "explain these concepts to a friend" among female students from different SES backgrounds. Specifically, female students from a low SES background had less positive perceptions in these areas compared to their counterparts from a general SES background. These disparities among female students can be attributed to a number of factors, such as gender stereotypes that discourage interest in technical fields (Master *et al*., 2016), a lack of female reference role models in fields such as "Science, Technology, Engineering, and Mathematics", ICT, and ML (Breda *et al*., 2020), as well as socioeconomic barriers that limit access to educational resources and opportunities (UNICEF, 2023; World Bank, 2023), and social expectations that can restrict their academic and professional aspirations (Domenico; Jones, 2006), which may be present more strongly in a low SES context.

For male students, a significant difference was observed only regarding their perception of the ability to explain 'what ML is' to a friend. For these students, there can be social pressures to excel in certain areas, such as ICT, which may lead to greater encouragement in these fields and show smaller differences between the groups (MIT, 2023). In addition, the dominant male representation in certain areas can create an environment where male students feel more encouraged to get involved with ML (MIT, 2023; GlobalStemYouth, 2021).

Concerning the educational stage, the study found significant differences in the perception of the ease of developing an ML model and the ability to explain 'what ML is' to a friend among middle and high school students from different SES backgrounds. However, no significant differences

were found for middle and high school students in their understanding of 'what ML is' and their perceived ability to develop an ML model. These results may be linked to differences in quality in their regular schools and learning across SES backgrounds, which can influence the development of these students (OECD PISA, 2019). Middle school students are at a stage where fundamental concepts are being formed, which can make them susceptible to the influence of the SES context on their learning experiences (Langenkamp and Carbonaro, 2018). In contrast, for high school students, significant differences were also found in perceptions of the learning experience not shown among middle school students. An explanation may be that high school students are at a stage where they are beginning to decide and envision their career options, which can also make them susceptible to the SES background (Mau *et al*., 2018).

Overall, the study's findings underscore the significance of tailoring the design and delivery of ML courses to attend students from different SES backgrounds in order to democratize the learning of ML. Educators must recognize that the students' SES background can influence their learning perceptions and experiences. To foster an inclusive educational environment, it is essential to equip students from a low SES background with the necessary technological resources and support to grasp and express ML concepts effectively. This support should also extend to other underrepresented groups, such as female students, ensuring they receive the same opportunities for success. It should also provide motivating experiences in the ML field, especially for high school students, who are on the path to making professional and academic choices. Moreover, teaching strategies should focus on making the learning process enjoyable and engaging for all students. This can be achieved through interactive content, practical demonstrations, and stimulating discussions, all of which can heighten students' interest and motivation in the subject.

Based on the findings, a summary of the key findings can be seen in Table 13 below:

Table 13: Summary of Key Findings.

Aspect Assessed	**Key Findings**
Perception of Learning	SES background can influence students' conceptual understanding and ability to explain ML.
	No significant SES differences in perceived ability to develop ML models or task difficulty.
Learning Experience	SES background can affect course enjoyment, perception of class time, and interest in ML.
	No SES differences in perceived course difficulty or overall course evaluation.
Sex Assigned at Birth	For females, SES differences observed in understanding/explaining ML; for males, only in explaining ML.
Educational Stage	SES differences in ease of developing ML models and explaining ML, especially in high school.
Implications	Practical activities may equalize learning perceptions; inclusive strategies are essential.

8.1 Practical challenges in implementation and dialog with recent literature

The implementation of ML courses for students from diverse socioeconomic backgrounds brings practical challenges that are directly aligned with recent literature in Informatics in Education. Studies such as Everson *et al.* (2022) and Zhang *et al.* (2022) highlight obstacles including the difficulty of translating theoretical concepts into practical applications, limited technological infrastructure, the need for ongoing teacher training, and motivational barriers faced by low SES students.

Our findings corroborate these challenges: students from low SES backgrounds demonstrated lower conceptual understanding and less ease in explaining ML, which may be associated with less prior exposure to technology and fewer resources in their schools. On the other hand, the perceived difficulty of practical tasks and the confidence to apply ML were similar across groups, suggesting that hands-on activities and accessible tools (such as Google Teachable Machine) can help mitigate some of the inequalities highlighted in the literature .

Moreover, the literature emphasizes the importance of active pedagogical strategies, project-based learning, and interdisciplinary integration to overcome engagement barriers and foster the development of problem-solving skills. Our experience, which included practical activities, peer tutoring, and individualized support, reinforces the effectiveness of these approaches, but also highlights the need for institutional policies, investment in infrastructure, and continuous teacher training to ensure the sustainability and scalability of such initiatives.

Finally, ethical challenges such as algorithmic bias and data privacy are also stressed in the international literature and should be incorporated into classroom discussions, preparing students for a critical and responsible use of AI/ML.

8.2 Future research

Overall, while this study provides valuable insights, it has some limitations. The data were collected from a specific course of ML (ML4ALL!) in Brazil, which may limit the generalizability of the findings. Future research could address these limitations by using a larger sample size and incorporating other data collection methods, such as interviews. It would also be interesting to explore the influence of other factors, such as peer tutors' effect in teaching support and the students' prior computing knowledge, on their learning perceptions and experiences in AI/ML education.

Furthermore, future implementations should broaden the ethical debate and promote partnerships among schools, universities, and the public sector to address structural challenges and ensure digital inclusion for all students.

9 Conclusion

The ML4ALL! course aims to democratize ML knowledge, making it accessible to a broad audience, particularly middle and high school students, regardless of their socioeconomic status. A comparative analysis of students' perception of their learning and learning experience reveals some significant differences, suggesting that the SES background can impact these perceptions. However, these differences do not hinder students' learning experiences or their understanding of ML, indicating that a specific SES background is not a barrier to learning ML. Yet, these findings underscore the importance of considering socioeconomic factors when designing educational strategies to create inclusive, engaging, and attractive learning conditions to all students, regardless of their SES background. Although the results suggest that SES may also be influenced by factors such as assigned sex at birth and educational level, these factors do not impair the students' learning experiences in ML. Further research is needed to corroborate these findings and deepen the understanding of the variables that affect students' learning perceptions and experiences in the AI/ML field.

Acknowledgements

Special thanks to all the participants in this study who took the time to fill in the data collection instruments, as well as to the entire team at the Vilson Groh Institute who supported the application. And thanks to the Federal Institute of Santa Catarina for the opportunity to carry out this research.

References

AI+. (2021). Developing an artificial intelligence curriculum adapted to European high schools. Retrieved from https://aiplus.udc.es/.

AI4ALL. (2023). Retrieved from https://ai-4-all.org/.

Agência Brasil. (2023). PISA: Less than half of Brazilian students know basic math, science. Retrieved from https://agenciabrasil.ebc.com.br/en/educacao/noticia/2023-12/pisa-less-half-brazilian-students-know-basic-math-science

Amershi, S., Begel, A., Bird, C., DeLine, R., Gall, H., & Kamar, E. (2019). Software Engineering for Machine Learning: A Case Study. Proc. of the IEEE/ACM Int. Conf. on Software Engineering: Software Engineering in Practice, Montreal, Canada, 291–300. https://doi.org/10.1109/ICSE-SEIP.2019.00042. [GS Search]

APA. (2023). American Psychological Association. Retrieved from https://www.apa.org/pi/ses/resources/publications/education.

Avvisati, F. (2020). The measure of socio-economic status in PISA: a review and some suggested improvements. Large-scale Assessments in Education, 8(8),2-37. https://doi.org/10.1186/s40536-020-00086-x. [GS Search]

Basili, V. R., Caldiera, G., & Rombach, H. D. (1994). Goal Question Metric Paradigm. In Encyclopedia of Software Engineering, pp. 646-661. Wiley. [GS Search]

Breda, T., Grenet, J., Monnet, M., & Van Effenterre, C. (2020). Do Female Role Models Reduce the Gender Gap in Science? Evidence from French High Schools (IZA DP No. 13163). IZA Institute of Labor Economics. [GS Search]

Camada, M. Y., & Durães, G. M. (2020). Ensino da Inteligência Artificial na Educação Básica: um novo horizonte para as pesquisas brasileiras. In: Simpósio Brasileiro de Informática na Educação (SBIE), 31. Porto Alegre: Sociedade Brasileira de Computação, p. 1553-1562. https://doi.org/10.5753/cbie.sbie.2020.1553. [GS Search]

Casal-Otero, L., Catala, A., Fernández-Morante, C., Taboada, M., Cebreiro, B., & Barro, S. (2023). AI literacy in K-12: a systematic literature review. Int. Journal of STEM Education, 10(29), 2-17. https://doi.org/10.1186/s40594-023-00418-7. [GS Search]

Chen, Q., Kong, Y., Gao, W., & Mo, L. (2018). Effects of Socioeconomic Status, Parent–Child Relationship, and Learning Motivation on Reading Ability. Frontiers in Psychology, 9, 1664-1078. https://doi.org/10.3389/fpsyg.2018.01297. [GS Search]

Destin, M., Hanselman, P., Buontempo, J., Tipton, E., & Yeager, D. S. (2019). Do Student Mindsets Differ by Socioeconomic Status and Explain Disparities in Academic Achievement in the United States? AERA Open, 5(3). https://doi.org/10.1177/2332858419857706. [GS Search]

Domenico, D. M., & Jones, K. H. (2006). Career aspirations of women in the 20th century. Journal of Career and Technical Education, 22(2), Fall 2006. ERIC Number: EJ901302. 1531-4952. Retrieved from https://files.eric.ed.gov/fulltext/EJ901302.pdf. [GS Search]

Elements of AI. (2023). Elements of AI. University of Helsinki. Retrieved from https://www.elementsofai.com/.

Everson, J., Kivuva, F. M., & Ko, A. J. (2022). A Key to Reducing Inequities in Life, AI, is by Reducing Inequities Everywhere First: Emerging Critical Consciousness in a Co-Constructed Secondary CS Classroom. In Proc. of the ACM Technical Symposium on

Computer Science Education, Providence, RI, USA, 209-215. https://doi.org/10.1145/3478431.3499395. [GS Search]

Finau, J. (2021). How socioeconomic status affects students. Capstone project, Liberal Studies Program, California State University, Chico. ScholarWorks. Retrieved from https://scholarworks.calstate.edu/downloads/qv33s2864. [GS Search]

Freitas, E. L. S. X., Bittencourt, I. I.; Isotani, S., Marques, L., Dermeval, D.; Silva, A., & Mello, R. F. (2025). Inteligência Artificial para Educação: Um Caminho para um Campo mais Inclusivo. Revista Brasileira de Informática na Educação, [S. l.], v. 31, p. 307–322. http://doi.org/10.5753/rbie.2023.3156. [GS Search]

GlobalStemYouth. (2021). The "Masculine" culture of STEM fields. Retrieved from https://www.globalstemyouthjournal.org/post/the-masculine-culture-of-stem-fields.

Google. (2023). Google Teachable Machine. Retrieved from https://teachablemachine.withgoogle.com/.

Google A. I. Experiment. (2022). Quick Draw!. Retrieved from https://quickdraw.withgoogle.com.

Governo Federal (2024). Destaques IDEB e SAEB 2023. Retrieved from https://todospelaeducacao.org.br/wordpress/wp-content/uploads/2024/08/todos-pela-educacao-destaques-ideb-e-saeb-2023.pdf

Gretter, S., Yadav, A., Sands, P., & Hambrusch, S. (2019). Equitable Learning Environments in K-12 Computing: Teachers' Views on Barriers to Diversity. ACM Transactions on Computing Education, 19(3), Article 24. https://dl.acm.org/doi/abs/10.1145/3282939. [GS Search]

Hash bits. (2018). Object Detector. Retrieved from https://play.google.com/store/apps/details?id=com.tecomen.android.objectdetector&hl=pt&gl=US.

IBGE. (2024a). One out of every four women aged 15 to 29 were not working or studying in 2023. Continuous PNAD. Retrieved from https://agenciadenoticias.ibge.gov.br/en/agencia-news/2184-news-agency/news/39543-one-out-of-every-four-women-aged-15-to-29-were-not-working-or-studying-in-2023.

IBGE. (2024b). Child education grows in 2023 and returns to pre-pandemic level. Summary of Social Indicators (SIS). Retrieved from https://agenciadenoticias.ibge.gov.br/en/agencia-news/2184-news-agency/news/42112-child-education-grows-in-2023-and-returns-to-pre-pandemic-level.

IBM. (2023). IBM SkillsBuild. Retrieved from https://skillsbuild.org/.

IVG. (2022). Pode Crer Program: 2022 Social Impact Report. Retrieved from https://vilsongroh.org/.

Langenkamp, A. G., & Carbonaro, W. (2018). How school socioeconomic status affects achievement growth across school transitions in early educational careers. Sociology of Education, 91(4), 358–378. https://doi.org/10.1177/0038040718802257. [GS Search]

Lee, I., Ali, S., Zhang, H., DiPaola, D., & Breazeal, C. (2021). Developing Middle School Students' AI Literacy. In Proc. of the ACM Technical Symposium On Computer Science Education,Virtual Event, USA. https://doi.org/10.1145/3408877.3432513. [GS Search]

Lee, I., Martin, F., Denner, J., Coulter, B., Allan, W., Erickson, J., Malyn-Smith, J., & Werner, L. (2011). Computational thinking for youth in practice. ACM Inroads, 2(1), 32-37. https://doi.org/10.1145/1929887.1929902. [GS Search]

Li, S., Xu, Q., & Xia, R. (2020). Relationship Between SES and Academic Achievement of Junior High School Students in China: The Mediating Effect of Self-Concept. Frontiers in Psychology, 10,1664-1078. https://doi.org/10.3389/fpsyg.2019.02513. [GS Search]

Long, D., & Magerko, B. (2020). What is AI literacy? Competencies and design considerations. In Proc. of the Conference on Human Factors in Computing Systems, Honolulu, HI, USA, 1–16. https://doi.org/10.1145/3313831.3376727. [GS Search]

Martins, R. M., & von Wangenheim, C. G. (2023). Teaching Computing to Middle and High School Students from a Low Socio-Economic Status Background: A Systematic Literature Review. Informatics in Education, 23(1), 179-222. https://doi.org/10.15388/infedu.2024.01. [GS Search]

Martins, R. M., von Wangenheim, C. G., Rauber, M. F., & Hauck, J. C. (2023a). Machine Learning for All!—Introducing Machine Learning in Middle and High School. International Journal of Artificial Intelligence in Education, 24, 185-223. https://doi.org/10.1007/s40593-022-00325-y. [GS Search]

Martins, R. M., von Wangenheim, C. G., Rauber, M. F., Hauck, J. C., & Silvestre, F. M. (2023b). Teaching Machine Learning to Middle and High School Students from a Low Socio-Economic Status Background. Informatics in Education, 23(3), 647-678. https://doi.org/10.15388/infedu.2024.13. [GS Search]

Master, A., Cheryan, S., & Meltzoff, A. N. (2016). Computing whether she belongs: Stereotypes undermine girls' interest and sense of belonging in computer science. Journal of Educational Psychology, 108(3), 424–437. https://doi.org/10.1037/edu0000061. [GS Search]

Mau, W.-C. J., & Li, J. (2018). Factors influencing STEM career aspirations of underrepresented high school students. The Career Development Quarterly, 66, 246-258. https://doi.org/10.1002/cdq.12146. [GS Search]

MEC. (2017). Ministério da Educação. Base Nacional Comum Curricular. Retrieved from http://basenacionalcomum.mec.gov.br/.

MIT OpenCourseWare. (2023). Retrieved from https://ocw.mit.edu/.

MIT. (2023). The gender gap in STEM: Still gaping in 2023. Retrieved from https://professionalprograms.mit.edu/blog/leadership/the-gender-gap-in-stem/.

MIT. (2017). MIT Moral Machine. Retrieved from https://www.moralmachine.net/.

Mitchell, T. M. (1997). Machine learning. McGraw-Hill.

OECD PISA. (2023). PISA 2022 results: Brazil [Factsheet]. Retrieved from https://www.oecd.org/publication/pisa-2022-results/country-notes/brazil-61690648/#chapter-d1e11.

OECD PISA. (2019). PISA 2018 Results (Volume II): Where All Students Can Succeed. OECD Publishing, Paris. https://www.oecd.org/en/publications/pisa-2018-results-volume-ii_b5fd1b8f-en.html. [GS Search]

Parker, M. C., & Guzdial, M. (2015). A critical research synthesis of privilege in computing education. In Proc. of Research in Equity and Sustained Participation in Engineering,

Computing, and Technology, Charlotte, NC, USA, 1-5. https://doi.org/10.1109/RESPECT.2015.7296502. [GS Search]

Perry, L.B., Saatcioglu, A., & Mickelson, R.A. (2022). Does school SES matter less for high-performing students than for their lower-performing peers? A quantile regression analysis of PISA 2018 Australia. Large-scale Assessments in Education, 10(17), 2-29. https://doi.org/10.1186/s40536-022-00137-5. [GS Search]

Rauber, M. F., von Wangenheim, C. G., Barbetta, P. A., Borgatto, A. F., Martins, R. M., & Hauck, J. C. R. (2023). Reliability and Validity of an Automated Model for Assessing the Learning of Machine Learning in Middle and High School. Informatics in Education. Online. https://doi.org/10.15388/infedu.2024.10. [GS Search]

Russell, S. J., & Norvig, P. (2016). Artificial intelligence: A modern approach. Pearson Education Limited.

Sharifani, K., & Amini, M. (2023). Machine Learning and Deep Learning: A Review of Methods and Applications. World Information Technology and Engineering Journal, 10(07), 3897-3904. [GS Search]

TeachAI. (2023). Retrieved from https://teachai.org/.

TIC Educação (2022). Pesquisa sobre o uso das Tecnologias de Informação e Comunicação nas escolas brasileiras. Cetic.br. Retrieved from https://cetic.br/media/docs/publicacoes/2/20231122132216/tic_educacao_2022_livro_completo.pdf.

Touretzky, D. S., Gardner-McCune, C., & Seehorn, D. (2022). Machine learning and the five big ideas in AI. Int. Journal of Artificial Intelligence in Education, Springer, Nature. https://doi.org/10.1007/s40593-022-00314-1. [GS Search]

Touretzky, D. S., Gardner-McCune, C., Martin, F., & Seehorn, D. (2019). Envisioning AI for K-12: What Should Every Child Know about AI? In Proceedings of the 33rd AAAI Conference on Artificial Intelligence, Honolulu, HI, USA, 9725-9726. https://doi.org/10.1609/aaai.v33i01.33019795. [GS Search]

United Nations. (2015). The 17 Goals. Department of Economic and Social Affairs, Sustainable Development. Retrieved from https://sdgs.un.org/goals.

UNESCO (2023). Global Education Monitoring Report Team - Global education monitoring report summary, 2023: Technology in education: A tool on whose terms? Document code: ED/GEMR/MRT/2023/S1/Rev. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000386147.

UNESCO. (2022). K-12 AI curricula – A mapping of government-endorsed AI curricula. Paris.

UNESCO. (2017). Reducing Global Poverty Through Universal Primary and Secondary Education. Policy Paper 32. Paris. https://uis.unesco.org/sites/default/files/documents/reducing-global-poverty-through-universal-primary-secondary-education.pdf.

UNICEF. (2023). Girls' education. https://www.unicef.org/education/girls-education.

UNICEF. (2021). The State of the Global Education Crisis: a Path to Recovery. A joint UNESCO, UNICEF and World Bank report. Geneva.

UNICEF Innocenti Research Centre. (2014). Quasi-Experimental Design and Methods. Retrieved from https://www.unicef-irc.org/KM/IE/impact_8.php.

Vekiri, I. (2010). Socioeconomic differences in elementary students' ICT beliefs and out-of-school experiences. Computers & Education, 54(4), 941-950. https://doi.org/10.1016/j.compedu.2009.09.029. [GS Search]

Visio.ai. (2024). Image recognition: The basics and use cases (2024 guide). Retrieved from https://viso.ai/computer-vision/image-recognition/.

von Wangenheim, C. G., Hauck, J. C. R., Pacheco, F. S., & Bueno, M. F. B. (2021). Visual Tools for Teaching Machine Learning in K-12: A Ten-Year Systematic Mapping. Education and Information Technologies, 26(5), 5733-5778. https://doi.org/10.1007/s10639-021-10570-8. [GS Search]

von Wangenheim, C. G., & von Wangenheim, A. (2021). Overview on a human-centric interactive ML process for teaching ML in K-12. Working Paper WP_GQS_01_2021_v10, GQS/INCoD/UFSC. Retrieved from http://www.gqs.ufsc.br/files/2020/02/GQSTemplate-RelatorioTecnico-HumanCentricProcess-v10.pdf. [GS Search]

von Wangenheim, C. G., Petri, G., Zibetti, A. W., Borgatto, A. F., Hauck, J. C. R., Pacheco, F. S., & Missfeldt Filho, R. (2017). dETECT: A model for the evaluation of instructional units for teaching computing in middle school. Informatics in Education, 16(2), 301-318. https://doi.org/10.15388/infedu.2017.15. [GS Search]

World Bank. (2023). Girls' education. Retrieved from https://www.worldbank.org/en/topic/girlseducation.

Yu, Y. (2023). Deep learning approaches for image classification. In Proc. of the International Conference on Electronic Information Technology and Computer Engineering, Xiamen, China, 1494-1498. https://doi.org/10.1145/3573428.3573691 [GS Search]

Zhang, H., Lee, I., Ali, S., Sargent, J., & Hsu, W. (2022). Integrating Ethics and Career Futures with Technical Learning to Promote AI Literacy for Middle School Students: An Exploratory Study. Int. Journal of Artificial Intelligence in Education. Online. https://doi.org/10.1007/s40593-022-00293-3 [GS Search]

Zhou, Y., Zhan, Z., Liu, L., Wan, J., Liu, S., & Zou, X. (2023). International Prospects and Trends of Artificial Intelligence Education: A Content Analysis of Top-level AI Curriculum across Countries. In Proc. of the 6th International Conference on Digital Technology in Education, New York, NY, USA, 337–343. https://doi.org/10.1145/3568739.3568796 [GS Search]