The Role of Mathematics Proficiency in Learning & Teaching ML

Rențea, Ilinca

DOI
10.1145/3724389.3731292

Publication date
2025

Document Version
Final published version

Published in
ITiCSE 2025 - Proceedings of the 30th ACM Conference on Innovation and Technology in Computer Science Education

Citation (APA)
Rențea, I. (2025). The Role of Mathematics Proficiency in Learning & Teaching ML. In *ITiCSE 2025 - Proceedings of the 30th ACM Conference on Innovation and Technology in Computer Science Education* (pp. 828-829). (Annual Conference on Innovation and Technology in Computer Science Education, ITiCSE; Vol. 2). ACM. https://doi.org/10.1145/3724389.3731292

The Role of Mathematics Proficiency in Learning & Teaching ML

Ilinca Rențea
I.E.I.Rentea@tudelft.nl
Delft University of Technology
Delft, The Netherlands

Abstract

Machine Learning(ML) has an overarching impact, yet misconceptions about its fundamentals result in unrealistic expectations. This highlights the need for targeted educational research on how to effectively teach ML to both professionals and the general public. This thesis explores the knowledge required to learn ML, with a focus on mathematical skills, their impact on learning, and strategies for adapting instruction to different levels of math proficiency.

CCS Concepts

• **Social and professional topics → Computer science education**.

Keywords

machine learning, education, foundational knowledge, prerequisite knowledge, mathematics

ACM Reference Format:
Ilinca Rențea. 2025. The Role of Mathematics Proficiency in Learning & Teaching ML. In *Proceedings of the 30th ACM Conference on Innovation and Technology in Computer Science Education V. 2 (ITiCSE 2025), June 27-July 2, 2025, Nijmegen, Netherlands.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3724389.3731292

1 Context and Motivation

Machine learning (ML) is a branch of computer science that focuses on methods to learn from data and improve their performance over time, being related to pattern recognition, computational statistics, and artificial intelligence [3, 8]. This technology has become increasingly widespread across professional fields, from industry 4.0 to creative industries. This overarching application creates a growing need for ML education across diverse audiences. However, a solid understanding of ML is often difficult to achieve, particularly due to the complex concepts that stand behind ML methods [5]. This gap between the widespread use of ML and the understanding of its fundamental principles has led to misconceptions about its capabilities and limitations [10].

Due to the aforementioned reasons, the field of ML educational research is starting to gain popularity. This effect is mainly influenced by the need for a clear and researched framework for teaching ML [6], as well as the need to educate tomorrow's users of ML and AI technologies. As suggested by Sarkar et al. [9], teaching a subject requires knowledge about difficult topics to learn, misconceptions, prerequisites needed for certain topics, and how students approach learning.

In this context, one challenge to be explored is the strong connection between ML and complex prerequisite knowledge, such as mathematics and statistics [1]. These mathematical foundations are crucial for understanding core ML concepts, but they often represent a barrier in students' learning.

2 Background

Mathematics represents a fundamental prerequisite for understanding and applying ML. At the same time, math and abstract concepts are believed to make ML difficult to learn and consequently to teach, as suggested by [5].

Since this perceived difficulty is generated by the abstraction level of mathematics concepts, it is relevant to analyze the Pedagogical Content Knowledge (PCK) researched in the context of math education. There is a systematic review [2] exploring how PCK has been conceptualized and studied in mathematics education. This review provides a foundation for understanding how mathematical knowledge is currently taught.

In the context of ML education, Grabarnik et al. [4] address the importance of prerequisite knowledge, using linear algebra as a key example of foundational math for STEM disciplines. Similarly, recent research introduces the concept of *just-in-time* prerequisites, which integrate math concepts into an ML course as needed, rather than refreshing all prior knowledge at the beginning of the course. This approach also aligns with the research performed by Maass et al. [7] that emphasizes the importance of mathematics education and suggests a better integration of it with STEM education.

Starting from this existing research, the goal is to explore the mathematical foundations necessary for learning ML, examining their impact on comprehension and identifying strategies to adapt instruction based on learners' mathematical backgrounds.

3 Problem Statement

ML education is gaining relevance in various fields while existing educational approaches either oversimplify the subject or ignore the role of mathematics in understanding ML concepts. The lack of clarity on how mathematical skills influence ML education represents a research gap and this study aims to investigate it. At the same time, it focuses on adapting ML education based on students' varying levels of mathematical proficiency.

To address these issues, the following research questions will be considered:

RQ1: What is the current status of Machine Learning education research? What are the identified challenges and the proposed strategies related to foundational knowledge in Machine Learning education research?

ITiCSE 2025, Nijmegen, Netherlands

ACM ISBN 979-8-4007-1569-3/2025/06
https://doi.org/10.1145/3724389.3731292

RQ2: How do math skills influence the learning experience of ML students?

RQ3: How do mathematics refreshers influence the learning experience of ML students as measured by learning outcomes and perception?

RQ4: How can ML education be adapted based on the math skills of the students?

4 Research Goals

The first goal of this thesis is to explore the role of math prerequisites in ML education and their impact on learners' understanding of ML concepts. Specifically, this study aims to determine the mathematical barriers that students encounter in their process and how these affect their learning. In the same time, this research aims to determine how effective math refreshers are in the context of a ML course.

Besides knowledge acquisition, this study also investigates non-cognitive learning factors, such as motivation, self-efficacy, and attitudes toward ML. Understanding how students perceive their ability to learn ML, and how their motivation evolves during the learning process will provide deeper insights. These learning factors will be studied in the same context, namely the one of math prerequisites.

This dual focus helps retrieve the general view of student learning, aiming to improve the conceptual understanding and to foster a more positive and sustainable learning experience.

5 Research Methods

This project will use multiple methods, combining qualitative and quantitative methodologies to analyze different aspects of ML education. First, a systematic literature review will be conducted to describe the current state of ML education research, identifying existing patterns, themes, challenges, and strategies in teaching ML, with a particular focus on foundational knowledge. This review will help establish a base for subsequent analysis. Second, a math prerequisite intervention will be implemented within a Bachelor-level ML course. This intervention will aim to examine how targeted instruction in mathematical foundations influences student understanding, engagement, and overall learning outcomes. Data collection will include pre- and post-tests, and student feedback. More than that, common problems students face while solving ML assignments will be collected using a language model system that provides personalized answers to students. Last but not least, analogies will be developed and introduced in teaching ML, especially for concepts that were identified in aforementioned studies as difficult to understand.

The studies will include participants from varying academic backgrounds with different levels of mathematical proficiency. A combination of different methodologies will be used to collect objective performance data and subjective measures such as motivation and self-efficacy. This mixed-methods approach will provide an understanding of how mathematical prerequisites influence ML education and inform the development of effective teaching strategies.

6 Contributions

This study aims to make the following contributions to the field of ML education:

(1) Comprehensive analysis of the current state of ML education research seen through the lens of mathematics
(2) Math prerequisite intervention in Bachelor level ML course
(3) Personalized system identifying common problems students face while solving ML assignments, and providing help
(4) Analogies in explaining difficult ML concepts

The first contribution will identify challenges and trends with a focus on prerequisite knowledge, particularly in mathematics. This will help sketch the research landscape and gain information for future research. More than that, it could serve as inspiration for instructors developing or improving an ML course, since it will include ML topics, and existing teaching strategies. In terms of progress, the research associated with this contribution is currently ongoing.

The second contribution will be the development and evaluation of a math prerequisite intervention to support students. By assessing the impact of targeted mathematical instruction, this research will offer evidence-based recommendations on how integrating mathematical foundations can enhance ML learning outcomes. This study is planned to be executed starting academic year 2025/2026.

Overall, this research will offer insights into the role of mathematical prerequisites in ML education, propose strategies for improving instructional approaches, and contribute to the broader discussion on how to make ML education more accessible and effective for diverse learners.

References

[1] Marc Peter Deisenroth, A Aldo Faisal, and Cheng Soon Ong. 2020. *Mathematics for Machine Learning*.
[2] Fien Depaepe, Lieven Verschaffel, and Geert Kelchtermans. 2013. Pedagogical content knowledge: A systematic review of the way in which the concept has pervaded mathematics educational research. *Teaching and Teacher Education* 34 (Aug. 2013), 12–25. doi:10.1016/j.tate.2013.03.001
[3] G. Dheepak and D. Vaishali. 2021. A comprehensive overview of machine learning algorithms and their applications. *International Journal of Advanced Research in Science, Communication and Technology* (2021), 12–23.
[4] Genady Grabarnik, Luiza Kim-Tyan, and Serge Yaskolko. 2020. Addressing Prerequisites for STEM Classes Using an Example of Linear Algebra for a Course in Machine Learning. (2020).
[5] Christian Herta, Benjamin Voigt, Patrick Baumann, Klaus Strohmenger, Christoph Jansen, Oliver Fischer, Gefei Zhang, and Peter Hufnagel. 2019. Deep Teaching: Materials for Teaching Machine and Deep Learning. In *5th International Conference on Higher Education Advances (HEAd'19)*. Universitat Politècnica València. doi:10.4995/HEAD19.2019.9177
[6] Amy J Ko. 2017. We need to learn how to teach machine learning. (Aug. 2017).
[7] Katja Maass, Vince Geiger, Marta Romero Ariza, and Merrilyn Goos. 2019. The Role of Mathematics in interdisciplinary STEM education. *ZDM – Mathematics Education* 51, 6 (2019), 869–884. doi:10.1007/s11858-019-01100-5
[8] Michael Paluszek, Stephanie Thomas, Michael Paluszek, and Stephanie Thomas. 2019. An overview of machine learning. *MATLAB Machine Learning Recipes: A Problem-Solution Approach* (2019), 1–18. ISBN: 1484239156 Publisher: Springer.
[9] Mahbub Sarkar, Laura Gutierrez-Bucheli, Sun Yee Yip, Michelle Lazarus, Caroline Wright, Paul J. White, Dragan Ilic, Thomas J. Hiscox, and Amanda Berry. 2024. Pedagogical content knowledge (PCK) in higher education: A systematic scoping review. *Teaching and Teacher Education* 144 (July 2024), 104608. doi:10.1016/j.tate.2024.104608
[10] E. Sulmont, E. Patitsas, and J.R. Cooperstock. 2019. Can you teach me to machine learn? An exploration of pedagogical content knowledge for teaching machine learning to non-majors. 948–954. doi:10.1145/3287324.3287392