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Implementing quality assurance practices in teaching machine learning in higher education

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The development of machine learning and deep learning (ML/DL) change the skills expected by society and the form of ML/DL teaching in higher education. This article proposes a formal system to improve ML/DL teaching and, subsequently, the graduates' skills. Our proposed system is based on the quality assurance (QA) system adapted to teaching and learning ML/DL and implemented on the model suggested by Deming to continuously improve the QA processes.

Keywords: *machine learning; deep learning; assurance quality; higher education.*
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1. Introduction

Machine learning (ML) and deep learning (DL) have evolved in various fields due to their relevance and popularity [1]. ML technologies have impacted our society and become part of our everyday life [2, 3]. For example, "public health" [4], "diagnostic medicine" [5], and "decisions about hiring and promotion" [6]. The impact of ML and DL in industry and academia involves a growing demand for graduates in (ML/DL) [7]. However, society expects specific skills of graduates in ML/DL: "proficiency in thinking, reasoning, synthesizing, problem-solving, conceptualizing, evaluating, and communicating" [8]. Therefore, higher education should strive to meet the requirements of society by producing graduates with strong skills and knowledge in ML/DL [9]. Moreover, higher education should construct its competitive ranking by assuring a high quality of teaching and learning ML/DL. In various research, authors emphasize that taking into consideration the specificity of this field of education when teaching ML/DL and most research focused on ML/DL education put out that the traditional forms of teaching ML/DL, must be enhanced by integrating practice and theory [9] and changed from the traditional "teacher teaches, students learn" model to a "teacher–student interaction" model [10]. To bridge this gap in teaching ML/DL in universities and high education, many studies emphasize professional practice teaching as an important teaching method that integrates theory with a practice focusing on applied machine learning. In [11], it is developed a new teaching mode by integrating hands-on projects into a machine learning course. The goal of this study is to combine theory with practice and provide extracurricular homework as needed to develop "thinking skills and basic skills" that students can use to resolve ML/DL problems. In order to evaluate the effect of the model, this study also proposes an evaluation method based on intelligent technology. Although, in Teaching machine learning workshop 2020 [12], the community highlight that balancing theory and practice was considered a major challenge when designing lessons for ML. Furthermore, in Teaching ML workshop 2021 [13], most papers focus on the use of projects as a foundation for learning to practice ML after being taught at the theoretical or conceptual level. In [7], it is emphasized both the deep importance of hands-on on ML and DL courses and the method to select projects that motivate the students. In [14], it is proposed to embed and organize project-based learning in ML courses aligned with "real-world tasks, including experimental design and execution, report writing, oral presentation, and peer-reviewing" [14]. However, in [11], authors reveal the important fact that even if a teacher

wants to incorporate hands-on in ML and DL courses, experimental courses are frequently of poor quality, with issues such as a "lack of comprehensiveness, professionalism, and inadequate engineering applications" [11]. To address this issue, both [9] and [11] suggest determining the training plan and experimental plan according to the requirements of society and the enterprise. And also, encourage the teacher to change to "double-qualified type, increasing the opportunities for enterprises to exercise, strengthen the social practice ability of teachers, so as to promote classroom practice teaching".

Thus, empirical evidence has suggested insufficient teacher preparation impacts student achievement outcomes, the request for high-quality graduates demands high-quality methods to teach and learn. Luo L. ensures that universities must manage to implement the reform of teaching methods by [9]:

— implementing the concept of "taking students as the main body and teachers as the leading role", teachers are encouraged to innovate in their practical teaching methods, to participate in high-end academic seminars related to practical teaching, etc.
— "Enriching classroom teaching methods" which can strengthen teacher–student interaction, cultivate students' ability to innovate, analyze and solve problems.

Previous works on ML/DL education, focus on how to enhance courses, curriculum, and teaching ML/DL activity and practices to ensure the learning validity of students, while the crucial issues remain neglected: "How should identify the performance of teaching and learning ML/DL? And "Which are the essentials elements to identify the performance of teaching and learning ML/DL?"

Therefore, the main issues to be addressed in the present study are as follows:

RQ1 – How does Higher Education ensure that students in ML/DL acquire appropriate skills, knowledge, and values expected by society?

RQ2 – What should be accepted as adequate performance levels of graduates? Our research questions with their motivations are described in Table 1.

Table 1. Research questions.

#	Research questions	Motivations
RQ1	How does Higher Education ensure that students in ML/DL acquire appropriate skills, knowledge and values expected by society?	Discover which appropriate skills, knowledge and values are expected by society
RQ2	What should be accepted as adequate performance levels of graduates?	Discover the assessment process measuring students' level of performance based on metrics or indicators

Since applied higher education and especially ML/DL department should be competitive in the global economy by providing high-quality graduates with appropriate skills, knowledge, and values expected by the market need [9], implementing quality teaching and quality assurance let them rethink their traditional paradigm of teaching and learning and carry out a reform of teaching and learning system as recommended by [9] to design curriculum, courses content and learning activity with a deep understanding of labor market.

The aim of the present study is to bridge the gaps that exist in previous studies and develop a framework to help stockholders of education of ML/DL to assess teaching ML/DL practices and also to ensure that the quality of the graduates in ML/DL is being maintained and enhanced. The main research question to be examined in the present study is knowledge, skill and practice in ML/DL field should be observed and controlled over the teaching and learning process by embedding an assessment process that allowed measuring students' level of performance and subsequently reduce a difference between where students are currently in their knowledge, skill, or practice and where they need to be to meet the requirements of business/organization.

2. Background

2.1. Quality teaching in higher education

Society and employers demand higher education institutions produce highly skilled graduates in ML/DL [15]. However, in many African countries, there is a strong link between low-quality of graduates and quality teaching [16]. Hénard and Deborah in [17] defined quality teaching as "QT is the use of pedagogical techniques to produce learning outcomes for students", this guide identified different dimensions involved in quality teaching as curriculum, course, learning activity, assessment of learning outcomes and also creating a learning environment. Therefore, they emphasizes that the main drivers behind promoting quality teaching in Higher education are ensuring that their education will conduct in gainful employment and will equip students with the abilities, skills, knowledge, and values needed to progress professionally over a lifetime. Also, implementing a quality teaching culture allows higher education institutions to synchronize with regional and national, and international educational norms. Although higher education institutions should take into consideration when promoting quality in education five elements: the teacher, the student, the curriculum, the learners' achievements, and teaching and learning approaches [15] to ensure that their graduates (output of the system) have the necessary skills, knowledge, and values needed (input) through learning and teaching activities (process). Figure 1 shows a quality teaching system.

Fig. 1. Teaching and learning process.

2.2. Quality assurance in higher education

In [16], it is suggested that "without well-coordinated, controlling, and maintaining appropriate quality teaching, higher education can not provide high-quality graduates", and in [19] they put out that controlling and supporting quality teaching is strongly related to quality assurance mechanisms. Quality assurance provides higher education the confidence to demonstrate their performance and their teaching quality and subsequently establish a strong link between higher education and the public (students, parents, employers, etc.). On the other hand, quality assurance ensures "quality enhancement and support continuous improvement of teaching and learning" [18] by the creation of appropriate, reliable, and significant measurement tools for checking, "through continuous monitoring and evaluation of performance, that higher education is continuously improving what it does and how it does it" [19]. Systems of QA have been applied in HEIs as baseline for "the development and support of excellence at all levels of higher education" [15]. [20] describe QA as a system of assuring that the output of quality teaching (graduate) meets the employer's intended expectations (input), both at:

— Internal quality assurance: internal processes developed by higher education to evaluate and enhance the quality of its students by establishing goals, objectives, and norms to achieve taking into consideration what society and employers expect [18–20].
— External quality assurance: external assurance, introduce a third party (audit, assessment, review, accreditation, accountability, etc.) to make sure that objectives, goals and standards were achieved [19, 20], and also can help to evaluate the credibility of the internal evaluation quality results [20].

2.3. Continuous quality improvement

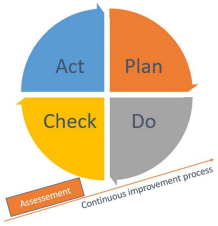

Fig. 2. Continuous quality improvement — Deming Cycle.

Continuous quality improvement, it is a strategy that promotes never-ending improvement using the plan-do-check-act (PDCA) cycle [20] as shown in Figure 2. To foster continuous improvement in education, firstly a set of learning objectives should be identified [17], because they: (1) provide to identify learning needs (knowledge, skills, and ethics); (2) guide the development of teaching and learning activities; (3) influence the design of adequate curriculum and courses (4) provide the assessment of the performance levels of

graduate. Then, higher education should use society/employers' feedback as an instrument for assessment of the teaching and learning process [17].

3. Methodology

The aim of this section is to describe the method adopted for the development of a quality assurance system to enhance and to assure continuous quality improvement in teaching and learning ML/DL process in higher education, according to a wheel management model suggested by Deming [21]. The Deming model is composed of: plan, do, check, act (PDCA), (Figure 2).

Plan: identify and specify a learning objective to achieve, define adequate performance Indicators, and put a plan into action.

Do: in this study this step is subdivided in two sub-steps:

Design: specify the students' profile, human and technical resources, infrastructure, cost, and time. Also design curriculum to be addressed and the content of high-quality courses, design learning activities, and define assessment of the student's learning. This step will be conducted by academic leaders or high-level professors.

Development:

— create teaching methods and tools that will be practiced in teaching and learning ML/DL, teaching methods may include lecture topics, demonstrations, exercises, methods to implement Algorithms, problem-solving activities, live coding, and so on. Teachers would drive this step because they have the role of developing, delivering educational programs and assuring their quality.
— review the relevance of quality objectives defined in phase 1, and monitor output (through KPI's) and outcomes against these objectives regularly. An evaluation committee is responsible of these tasks.

Check: analyze the skills gap to predict the results of an improvement act.

Act: identify and plan the best methods to address the skill gaps in teaching and learning ML/DL process. The method chosen depends on the higher education budget and needs skill. For example:

— preparation of the learning environment;
— training of the teachers;
— innovations in teaching practice;
— Enriching classroom teaching methods;
— ....

4. Design an overarching quality assurance framework

This step aims to identify the most essential elements of our proposed QA and the relation between them as shown in Figure 3.

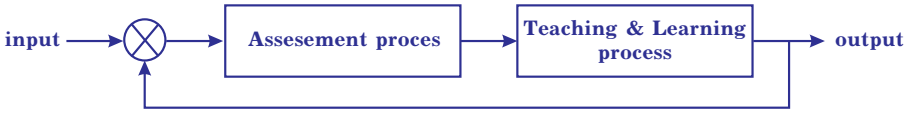

Fig. 3. Overarching quality assurance framework.

Input: (requirements): The input of our system is the ML/DL skills, domain knowledge and values required by employers (i.e., demand).

Output: (product): it involves in our studies students' outcomes (students' ability to innovate, analyze and solve problems). University should strive to satisfy society's requirements and ensure that product (graduates) has acceptable and adequate performance levels of skills, knowledge, and values.

Teaching and learning process: it is the inevitable element in our QA framework. This process involves equipping students with the values, skills and knowledge expected. The Key components of this process include curriculum and courses design and delivery, designing learning activities, resources quality, technology used in teaching and learning, classroom teaching methods and evaluation modes and delivery.

Assessment process: the aim of the assessment process is to ensure continuous improvement and subsequently the assessment of teaching and learning process. The assessment process is based on the performance metrics required to meet the quality objectives. Thus, the assessment process identifies teaching and learning process's progress as well as gaps in consistency of the process.

Feedback: There is a clear link between input and output to assure the quality of the graduates' performance Outcomes. Thus, higher education should monitor and measure the gaps between skills, knowledge and values expected and skills, knowledge, values acquired by student and consequently identify where improvements are required in teaching and learning process.

This step reveals the important concept in our QA framework, it is about learning objectives to achieve and also the performance metrics to measure and monitor the graduates' performance Outcomes.

5. Implementation of quality assurance practices

The implementation of our framework is based on the result of two surveys conducted by Kaggle [22] and Great Learning [23]. Those surveys define the essential skills, domain knowledge and values needed. Skills in ML/DL are represented in two categories [24]: hard skills (technical, programming and programming languages skills) and soft skills (behavior skills).

Table 2. Skills required in ML/DL fields.

Technical skills	**Programming skills**	**Programming Languages**	**Soft skills**
Applied mathematics	Computer Science Fundamentals and Programming	C, C++ and Java	Good understanding of the domain of machine learning
Physics	Software Engineering and System Design	Spark and Hadoop	Communication Skills
Advanced signal processing techniques	Machine Learning Algorithms and Libraries	R Programming	Problem-solving skills
Audio and video processing	Distributed computing	Apache Kafka	Rapid prototyping skills
Neural network architectures	Unix	Python	Time management
Data modeling and evaluation		Weka Platform	
Natural language processing			
Deep learning and artificial intelligence			

The analysis of those surveys allow to address our first question: "How does higher education ensures that students in ML/DL acquire appropriate skills, knowledge and values expected by society?". The goal of this question is to emphasize, firstly, the significant learning objectives linked back to society/employers' requirements, then measure the feedback of the learning outcomes, and, finally, identify the gap between skills/domain knowledge expected and the outcomes of the teaching and learning ML/DL process (skills acquired by graduates).

5.1. Learning objectives

Learning objectives are linked back to society/employers' requirements to define what higher education should provide to a labor market. Learning objectives are developed in consultation with an evaluation committee composed of academic leaders or high-level professors and a relevant stockholder. Table 3 summarizes our proposed learning objectives for our quality assurance framework.

Table 3. Learning objectives.

Skills required	Corresponding learning objectives
Technical skills	LO1: ability to apply knowledge of mathematics and physics. LO2: ability to work with ML/DL concepts and techniques
Programming skills	LO3: ability to have hands-on expertise in software programming and related concepts.
Programming language skills	LO4: ability to apply the concepts of computer science and programming language as the scenario requires.
Soft skills	LO5: ability to communicate effectively. LO6: ability to analyze data, generate a good model and create hypotheses, results and tests.

5.2. Measure the performance of learning outcomes: continuous quality improvement

The assessment process is a process for monitoring in our framework. This process aligns to the graduates' learning outcomes to improve it by identifying and reducing gaps between required skills by the employers and skills possessed by graduates. The achievement and adequate performance levels of graduates should be evaluated in relation to the learning objectives by implementing performance indicators. Performance indicators allow higher education institutes to ensure the performance of teaching ML/DL from inputs to outcomes and feedback.

Identifying the performance of learning outcomes allow to address our second question RQ2: "What should be accepted as adequate performance levels of graduates?" The goal of this question is to identify the means to measure the performance of learning outcomes.

In this study, we propose ten (10) performance indicators, summarized in Table 4.

Table 4. Performance indicators.

LO1: ability to apply knowledge of mathematics and physics	
PI1	Apply mathematics to choose the right algorithm, work with parameters and their settings
PI2	Apply physics to make a difference in designing complex systems
LO2: ability to work with ML/DL concepts and techniques	
PI3	Apply Machine learning/Deep learning concepts in predictive analytics
PI4	Apply data modeling concepts to work with huge amounts of data
PI5	Apply signal, image and video processing to extract the best features
PI6	Apply the basic concepts of reinforcement learning
LO3: ability to have hands-on expertise in software programming and related concepts	
PI7	Apply programming and coding task when executing a hands-on
LO4: ability to apply the concepts of computer science and programming language as the scenario requires	
PI8	Apply programming languages to train machines
LO5: ability to communicate effectively	
PI9	Apply communication techniques to communicate the results obtained and the solution adds value
LO6: ability to solve problems	
PI10	Analyze data, generate a good model and create hypotheses, results and tests

At the beginning, the evaluation committee, will attribute a value to acceptable adequate performance levels of graduate then measure the performance of student using performance indicators to identify the skill gaps as shown in Figure 4.

The role of the evaluation commission is not only to analyze skill gap but also, to propose how higher education address the skill gaps and promote continuous quality improvement by reviewing periodically the outcomes, and the learning objectives.

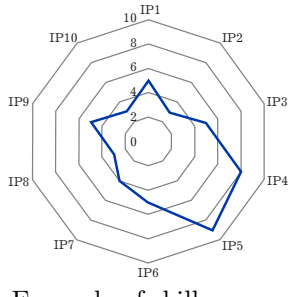

Fig. 4. Example of skill gaps analysis.

6. Conclusion

In this work, we analyzed and synthesized different studies focusing on improving teaching ML/DL to reveal the current situation and issues of ML/DL teaching. Those studies focus on three patterns: the teacher, student, and curriculum. However, to improve quality education to teach fundamental ML/DL concepts and techniques in higher education, we should consider the whole education system. This study proposed a framework to improve teaching ML/DL and assuring continuous quality improvement and its implementation by identifying learning objectives and subsequently the performance indicators of learning outcomes to ensure continuous quality improvement of our framework. Our system will be developed in our next research by integrating sustainable education into the learning and teaching process.

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Впровадження практик забезпечення якості у викладання машинного навчання у вищих навчальних закладах

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Розвиток машинного та глибокого навчання (ML/DL) змінить навички, очікувані суспільством, і форму викладання курсів ML/DL у вищій освіті. У цій статті пропонується формальна система для покращення викладання ML/DL і подальшого вдосконалення навичок випускників. Запропонована система базується на системі забезпечення якості (QA), адаптованій до викладання та вивчення ML/DL і реалізованій за моделлю, запропонованою Демінгом для постійного вдосконалення процесів забезпечення якості.

Ключові слова: *машинне навчання; глибоке навчання; гарантія якості; вища освіта.*