The Design of An Adaptive E-learning Model Based on Artificial Intelligence for Enhancing Online Teaching

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Abstract—Nowadays, teaching involves more and more the usage of digital tools to accompany face-to-face learning. Such a system is being referred to as hybrid teaching. These digital tools include mainly distance learning platforms based on LMS (Learning management systems). LMS help to create on-line digital spaces to store and organize teaching material while providing a pedagogical learning process to connect educational communities. Despite the many forms of content that can be implemented on these platforms, from traditional file-based to interactive and animated content, these systems remain both passive and generic. They lack the ability to adapt to the learner in terms of learning skills, preferences, languages, intellectual abilities, learning patterns and rhythms. This paper proposes a design and modeling of an intelligent and dynamic adaptive learning system based on artificial intelligence with the main objective of identifying and providing personalized learning environments adapted to the learner needs.

Keywords—adaptive learning architecture, UML modeling, adaptive learning, artificial intelligence, learning style, natural language processsing, deep learning, machine learning

1 Introduction & problematique

The importance of information and communication technologies (ICT) in the world of education has been observed even more during the health crisis of COVID-19. ICTs seem to create new avenues and innovative approaches for optimizing the quality of teaching and improving the learning process.

In recent years, we have witnessed a computer stabilization of Information and Communication Technologies (ICT) in the service of education and training. This stabilization allowed trainers and learners to take benefit from relatively standardized and mutually compatible tools. The democratization of the Internet in the 1990s favored further this compatibility. Today, there is a set of information, communication and training tools such as e-mail, chat, discussion groups, mailing lists, video-conferencing and hypertext/hypermedia. In addition, training organizations and universities are developing tele-training platforms integrating these tools to ensure the management and distribution of distance courses as well as the monitoring of learners. It seems interesting to lead here, a reflection on enhancing the design models of these platforms to assess the evolution of their effectiveness.

We will first recall what a teaching and training platform is. Online course platforms are software tools whose role is to allow the management of distance learning content. Computer vocabulary conventionally uses the term Learning Management System (LMS). LMSs are software solutions designed for course management, learner tracking and (online) delivery of learning content [1]. Several expressions are used to designate LMS such as: online learning platform, learning management system, virtual training center, e-learning platform and Open and Distance Learning (FOAD). Indeed, many studies attest that distance learning is even more effective, efficient, and accessible if teaching approaches are personalized and adaptive, in other words, if teaching strategies are in accordance with the Adaptive Learning System (ALS) [2].

An adaptive learning system must guarantee a unique and personalized learning path for each learner, it is mainly used to group learners with similar profiles in order to learn while preserving their motivation and commitment to learning [3]. Indeed, an adaptive learning system ensures distance learning adapted to the needs of the learners according to three levels: content, navigation and presentation.

The problem of the dynamicity and adaptability of distance learning platforms has attracted the interest of researchers in the field, with a focus on the development or use of new approaches for upgrading these platforms. In the literature, there are several approaches to personalize learning paths to learner profiles, including: artificial intelligence, big data, neuroscience, neuropedagogy and robotics, etc [4–8].

In this paper, we propose a design of an adaptive online/offline e-learning device based on artificial intelligence that includes the main components allowing the personalization of learning paths. The proposed model takes as inputs: the learning styles, skills, needs and preferences of each learner. These inputs will be then processed based on a set of artificial intelligence techniques.

The rest of this paper is structred as follows: the first section provides a description of of adaptive learning and its different solutions. The second section presents the architecture of the proposed intelligent learning system (ALSAI: Adaptive Learning System based Artificiel Intelligence), as well as a collection of possible concepts considered in this system. The third section presents the modeling axes of an adaptive online learning platform as well as a UML modeling of the proposed ALSAI solution. The last section concludes the paper and summarizes the perspectives of the next work.

2 Literature review

In this section, we will mostly focus on presenting an overview of adaptive e-learning as well as the different approaches employed in the context of adaptive digital learning and then we present the learning styles most commonly cited in the literature.

2.1 Adaptive online learning

The adaptive learning system improves the efficiency of online teaching by providing personalized content and user interfaces. It is a multidisciplinary field that integrates different sectors of computer science (software engineering, networks, modeling of knowledge and interactions) and human sciences (psychology, didactics, communication sciences and ergonomics) [2].

According to [9], adaptive learning is the process that enables the creation of a unique learning experience for each learner in accordance with his personalities, interests, and performances. In other words, adaptive E-learning refers to online learning systems that identify and process the different profiles of learners and thus offer a solution adjusted to their characteristics and meet the needs of learners to ensure continuous improvement and enhancement of their learning process.

2.2 Levels/mechanisms of adaptation

Several adaptation mechanisms have been discussed in the literature; while the most well known are those proposed by Brusilovsky and Paterno. According to these two researchers, there are three levels of adaptation: content adaptation, navigation adaptation, presentation adaptation [10], [11].

a. **Content adaptation**
   Content adaptation consists mainly in recommending content (text, image or video…) that matches the learner's knowledge, preferences and activities. The implemented content can be adapted either through the addition of specific content to the information provided by the learner, or through the elimination of content considered irrelevant to the learner's needs and preferences, or through the choice, among several predefined alternatives for the proposal of information, of the one that is the most adequate for a given user [12].
b. **Navigation adaptation**
   The aim of navigation adaptation is to prevent learners from clicking links that lead to content that is inappropriate for their needs. This can be accomplished by changing the target of the link, its annotation, its appearance order, or even the number of links that are presented to the parties involved.
c. **Presentation adaptation**
   Presentation adaptation consists in suggesting visual forms and characters that are customized to the preferences and requirements of the learner. This can be accomplished by adapting the layout of the platform's proposed components (colors, shape, size, font, background, etc.), or by personalizing the presentation of the page to the learner's chosen language.

2.3 New technologies and adaptive learning

Adaptive learning is a subject that has interested many scientific researchers, which has led to the design of several solutions. These solutions can be classified according to the approaches used into five categories:

– Rule-based approaches [13], [14]
– Approach based on fuzzy logic [15]–[16]
– Ontology construction approaches [17], [18]
– Competency-based approaches [19], [20]
– Approaches based on Artificial Intelligence techniques: machine learning, deep learning or genetic algorithms, etc… [21]–[23]

In a work carried out by [13], authors proposed a method based on generic rules, that are developed in an automatic way. This is in order to offer unique and personalized content to learners as well as an interface adapted to the learning styles of each learner, that the automatic detection of the characteristics related to a learner remains faced with a high level of uncertainty and imprecision.

It is in this sense that [24] proposed the integration of fuzzy logic in adaptive learning, in order to guarantee a more precise approach allowing to have an aptitude to detect the characteristics of learners and adapt the contents while dealing with the problem of uncertainty and imprecision.

Another approach is presented by [25], based on the use of ontologies with artificial agents based on the ACO (Ant Colony Optimization) meta-heuristic. This is to provide for each learner a training path adapted to his needs.

In the same context, [26] suggested a new model of adaptive learning that is based on Big Data technology and more precisely using the Map-Reduce based genetic algorithm and the Ant Colony Optimization algorithm for path personalization.

Still in the process of adaptation and personalization of learning activities, authors in [27] proposed a skill-based approach based on a meta-model of competence, which is also based on the IMS RDCEO and HR-XML specification. Finally, several scientific researchers have opted for artificial intelligence techniques such as Bayesian networks, supervised learning, unsupervised learning and genetic algorithms.

Referring to probability models, [28] proposed an "ALS_CORR[LP]" learning device based on the Bayesian network as well as on the learning styles defined by Felder and Silverman. On the other hand, several machine learning based approaches were identified in the literature. [29] and [30] focused on artificial intelligence techniques (Deep learning) to be applied for the different stages of online learning in order to personalize the learners' paths, namely LSTM neural networks.

In the following way, authors in [31] suggested a learning style prediction approach for adaptive e-learning, relying on unsupervised learning (K-means), in order to group learners according to their styles, as well as the use of supervised learning (Naive Bayes), with the aim of predicting the learning style of new learners. And in order to personalize the learning path [32] proposed the application of supervised learning (decision tree). Among the most used algorithms in adaptive learning is the "Genetic algorithm", which is used to offer learners different concepts to adopt in an optimal way while looking for the most appropriate objectives according to their profiles [33].

2.4 Learning styles

The notion of learning style is based on the diversification of learning methods among learners. The process of reception, analysis and restitution of information among learners differs from one to another. In other words, some learners rely on diagrams to understand a course, others favor videos, while others prefer specific programs that emphasize practice. In the literature, there are several models that define learning styles, we distinguish three models most used in adaptive learning systems, namely:

a) Felder and Silverman's model;
b) Kolb's model;
c) Honey and Murnford model.

The first model of Felder and Silverman is considered as the most popular in the world of adaptive learning. In fact, this model describes the different categories of learners [34]. FSLSM defines four dimensions namely preprocessing, perception, grasping and comprehension. This model (Figure 1) is divided into 8 types of learners: active, reflective, responsive, intuitive, visual, verbal, sequential, and global [35].

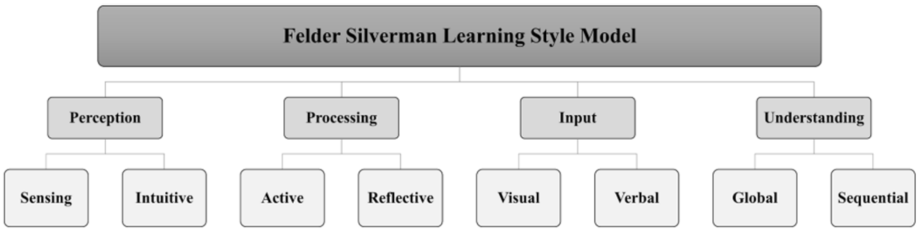

Fig. 1. Felder Silverman learning style model [36]

Several approaches and algorithms for automatic detection of learning styles have been designed based on this model. Kolb's model consists of combining two bipolar dimensions (convergent/abstract; action/reflective) to present four learning styles: convergent (active abstract), divergent (reflective concrete), assimilative (reflective abstract), and accommodative (active concrete) [37]. Finally, there is Honey and Murnford's model that is based on four learning styles: activist, theorist, pragmatist and reflector [38].

2.5 Adaptive learning method based on AI

Being an active area of research and development, several models of adaptive learning have been designed. The Table 1 below exposes some interesting works on the modeling of adaptive systems based on artificial intelligence.

Table 1. Interesting works on the modeling of adaptive systems based on artificial intelligence

Author	Publication	Date	Description
H. A. El-Sabagh	[39]	2021	The paper proposes a design of an adaptive online learning environment based on VARK learner learning styles and investigated the impact of adaptive online learning environment on student engagement.
U. Apoki, S. Ennouamani, H. Al-Chalabi, and G. C. Crisan	[40]	2020	Authors propose an adaptive e-learning system model that has the capability to integrate many features and weight them according to the magnitude of impact in a learning scenario. In addition, they suggest the addition of educational agents that should serve as assistant tutors during the learning process.
V. Vagale, L. Niedrite, and S. Ii	[41]	2018	The paper presents a personalized adaptive e-learning system architecture based on the learner model, and which is mainly based on three components, namely: the learner model, the content model and the adaptation model.
S. V. Kolekar, R. M. Pai, and M. Pai M. M	[42]	2018	Authors propose an architecture of the adaptive e-learning system for the e-learning application based on Moodle and the model of FSLM in order to detect the learning styles of the learners.
V. Kasinathan, A. Mustapha, and I. Medi	[43]	2017	The authors of this article presents a design of an adaptive learning system for readers and students. The proposed system is designed to optimize learning based on a unique learning pace in classrooms. This system has the ability to analyze the level of understanding of the students according to the cognitive level required in each module.
M. S. Rezaei and G. A. Montazer	[44]	2016	The article presents a new adaptive learning system based on an automatic and intelligent learner grouping approach. The approach used in this system consists of four steps, identify group structures, classify learners into identified groups, detect group expiration and edit learner groups.

3 Adaptive e-learning system based on artificial intelligence

Artificial intelligence (AI) refers to a collection of theories and methods that mimic human intelligence and enable computers to perform some cognitive functions, such as learning and reasoning. The areas in which the IA is applied are constantly expanding. These areas include the fields of health, industry, banking, finance, and business, as well as the fields of transportation, security, and education.

Nowadays, IA plays a crucial role in the sector of education, particularly in the implementation of adaptive learning systems [45]. In fact, this technology enables online learning platforms to adjust their content, navigation, and presentation to the preferences, skill levels, requirement, and learning goals of each learners. This is accomplished by relying on a variety of machine learning and deep learning algorithms.

Several methods are applied to implement an adaptive learning system. The Table 2 below outlines some interesting methods based on artificial intelligence (Machine Learning, Deep Learning…).

Table 2. Interesting methods based on artificial intelligence (Machine Learning, Deep Learning …)

Author	Publication	Method Used	Date	Description
Z. Shahbazi and Y.-C. Byun	[46]	Natural Language Processing (NLP)	2022	The authors applied here the NLP techniques to explore the textual content, in addition they identified learning styles based on learner's characteristics.
S. Alshmrany	[47]	Convolutional Neural Network-based Levy Flight Distribution (CNN-LFD)	2022	This article proposed a CNN-LFD algorithm to predict the learning style of learners.
A. Jain and H. Ram Sah	[48]	Deep Learning Convolutional Neural Network (CNN)	2021	The authors of the paper implemented an analysis approach (video/image) for real-time facial expressions, so as to recognize the quality of understanding and the active involvement of the participants in the process of learning and learning. This based on the algorithm of CNN in order to classify.
M. Modak, O. Warade, G. Saiprasad, and S. Shekhar	[49]	Natural Language processing (NLP) & Machine Learning (Support Vector Machine (SVM), Logistic Regression (LR))	2020	This paper proposed a system for detecting two profiles of learners, namely students with a learning disability (LD) and without learning disability (non-LD) based on NLP and Machine learning (LR, and SVM).
G.-J. Hwang, H.-Y. Sung, S.-C. Chang, and X.-C. Huang	[50]	Fuzzy expert system	2020	The authors describe here their implementation of an adaptive learning system based on a fuzzy expert system that takes into account the cognitive and affective factors of the learner.
I. Azzi, A. Jeghal, A. Radouane, A. Yahyaouy, and H. Tairi	[51]	Fuzzy C Means (FCM)	2020	This article outline a classifier that identifies the learner's learning style in an online learning system, based on the categories of the FSLSM model and using the FUZZY C Means algorithm to cluster the data.

3.1 Criteria considered in an adaptive e-learning system

Before starting the modeling of our adaptive learning system, it is essential to define the possible criteria taken into consideration in the development of an adaptive online learning system. These criteria can be summarized in three elements: learner needs, learner preferences, and Learning rhythms, as depicted in Figure 2.

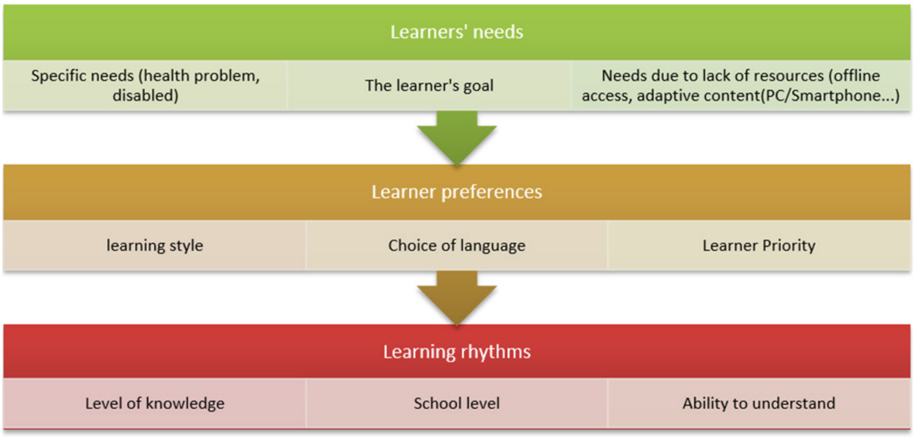

Fig. 2. Fundamental concepts considered in an adaptive e-learning system

3.2 Modeling axes of an adaptive e-learning platform

Adaptive learning platforms are based on a set of modeling axes, which also depend on the components of the e-learning device. The Table 3 below presents the different modeling axes of an adaptive e-learning platform:

Table 3. Modeling axis of an adaptive e-learning platform

Theme	Description
Pedagogical	– Construction of different pedagogical scenarios while considering the diversified paths of each learner in order to reach their objective.
Analysis	– Selecting relevant data that will allow the identification of profiles for each learner; – Analyzing of the data collected for each learner; – Grouping of similar profiles; – Adjusting the course proposals according to the analyzed data on an ongoing basis.
Technological	– Make available the different resources and pedagogical contents; – Make available the appropriate design, collection, analysis and communication tools.

3.3 Adaptive e-learning device

Today, online learning platforms represent an essential solution in the academic world, the use of these platforms has become a necessity in order to access educational content and acquire knowledge from environments different from physical classes.

It is in this sense that many online learning platforms have appeared such as Moodle, Caroline Connect, Sakai, Ilias, Canvas Network, Atutor, etc.

However, the main weakness of these platforms is the lack of adaptability. In other words, the majority of E-learning platforms that exist on the market are not adapted to the 3 mechanisms of adaptation. Moreover, almost all platforms were designed about ten years ago, and although new versions have been developed, implementing several enhancements such as personalized navigation, the content and the learning process still remain static [52].

The integration of artificial intelligence in online learning platforms is the best solution to address the static limitation, and this via the various technologies offered by AI. That allow the automation of the learning processes, detection of learner profiles (classification and prediction of profiles), automatizing the content translation (NLP), content classification, text processing, image and video processing, fraud and plagiarism, etc.

we present in this paper an adaptive, intelligent and dynamic device, based on intelligence technologies and more specifically machine learning, deep learning and natural language processing called (ALSAI: Adaptive Learning System based Artificial Intelligence). The proposed device is based on the adaptation of the three levels defined by Brusilovsky, namely: content, navigation and presentation. The main objective of this work is to accommodate the learners requirements in term of preferences and learning pace. The proposed architecture is described as follows:

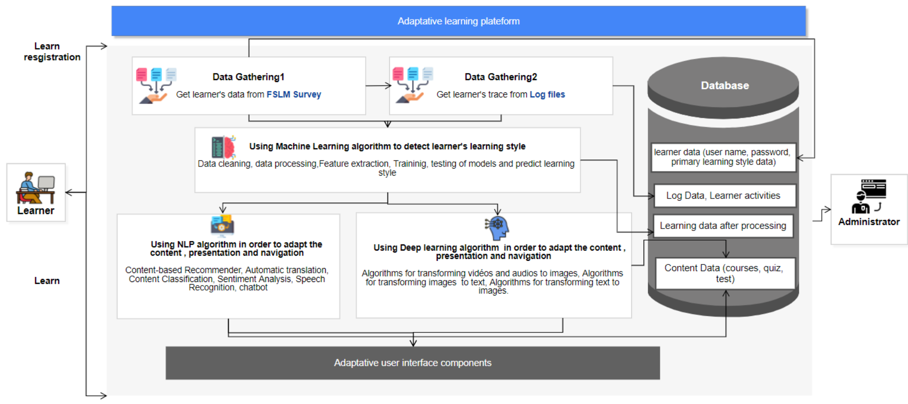

Fig. 3. Adaptive learning system based artificial intelligence (ALSAI)

The system architecture described by Figure 3. The is essentially based on the integration of new artificial intelligence technologies (machine learning, deep learning text mining). It is composed of three phases: the first phase is composed form two consecutive tasks. The first task consists on collecting and extracting the learner's attributes from the FSLM questionnaire. In fact, this phase takes place directly after the registration where the learner has to answer the FSLM questionnaire. This step is very important because it allows a classification of the learners according to the 8 learning categories of the FSLM: active, reflective, sensitive, intuitive, visual, verbal, sequential and global. However, the result of this phase is not efficient, this is due to the fact that the FSLM questionnaire contains 44 questions. So, the length of this questionnaire may be a possible cause of careless responding, we may then have random answers and irrelevant results since the presence of careless responding (CR) threatens the validity of inferences [53] and [54] made from self-report data. In addition, individual learners are not able to judge their knowledge level, or learning style/pace. Moreover, the pace and level of learning of each learner changes over time depending on the environment, age, grade level…and therefore the questionnaire alone cannot be considered as a reliable and relevant source to detect the learning style of a learner.

In this regards, and in order to improve the result of profile classification, the proposed model applies an additional second phase of collection. In other words, after collecting the students' answers and assuring a first interaction of the learner with the system, the latter analyzes the log files of the learner just after the use of the platform, in order to memorize the traceability of the paths of the different learners through the interaction with the system. The second phase consists in processing the data collected in the first phase. This is done through the application of self-learning algorithms to automatically classify and group learners according to their learning style and identified needs.

Finally, the third phase is based on the application of deep learning algorithms to perform data transcoding. Data transcoding is an approach that creates a more adaptive and accessible presentation of a content by matching the learner's requirements with the original content preferences and presentation [2]. This approach allows the transformation of audio/video into text or the transformation of image into text and vice versa. It therefore allows the adaptation of the content presentation according to the learner's profile.

Then, in order to adapt to the learner's preferences in terms of language choice, and to process the content set up by the teachers as well as the learners' comments on the content, the system applies Natural Language Processing (NLP) algorithms. The goal of this technology is to enable machines to read, decipher, understand and make sense of human language.

4 UML modeling of the ADAPLS (adaptive learning system) solution

The modeling of this platform relies on the involvement four main actors: the learners, the instructor and the system.

4.1 The use case diagram

- **Learner:**
  As shown in Figure 4. The main role of this actor is learning, and in order to perform this role, the learner starts with a registration on the platform. During this registration, a lot of information is requested (name, surname, school, department, CIN, CNE, etc.) and among these, the system asks for answers to the FSLM questionnaires

which includes 44 questions, in order to be able to manage his profile but also for the triggering of the adaptation of courses. After the registration phase, the learner can consult the available courses that correspond to his need or level. The learner can take quizzes/tests, consult the results, download the courses, communicate with the teacher, and participate in forums. He can also modify it's profile or follow a particular program.

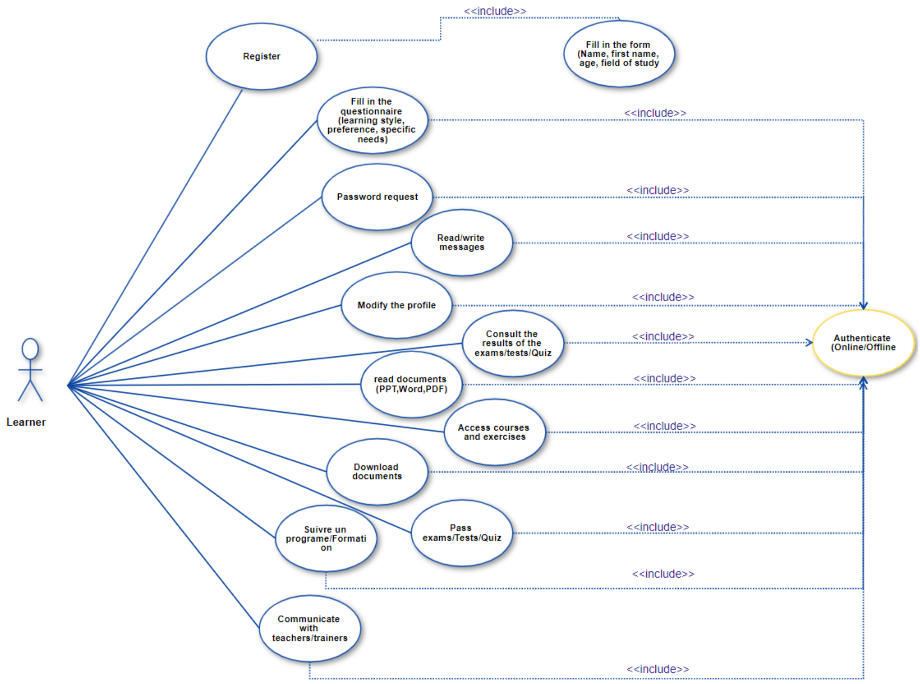

Fig. 4. Use case diagram for learners

- **Instructor:**
  As illustrated in Figure 5. The main role of this actor is to transmit knowledge, and in order to carry out this role, the instructor begins by registering on the platform. During the registration process, the teacher is asked for a number of information (name, surname, school, department, CIN, etc.) and among these, the system asks for answers to a questionnaire of x questions that allows to know the specific needs and the main objectives of the teacher. After the registration phase, this actor can read the messages sent by the students, answer them, modify his profile and participate in the forums. In addition, the teacher can write quizzes, edit lessons and exercises, and plan lessons.

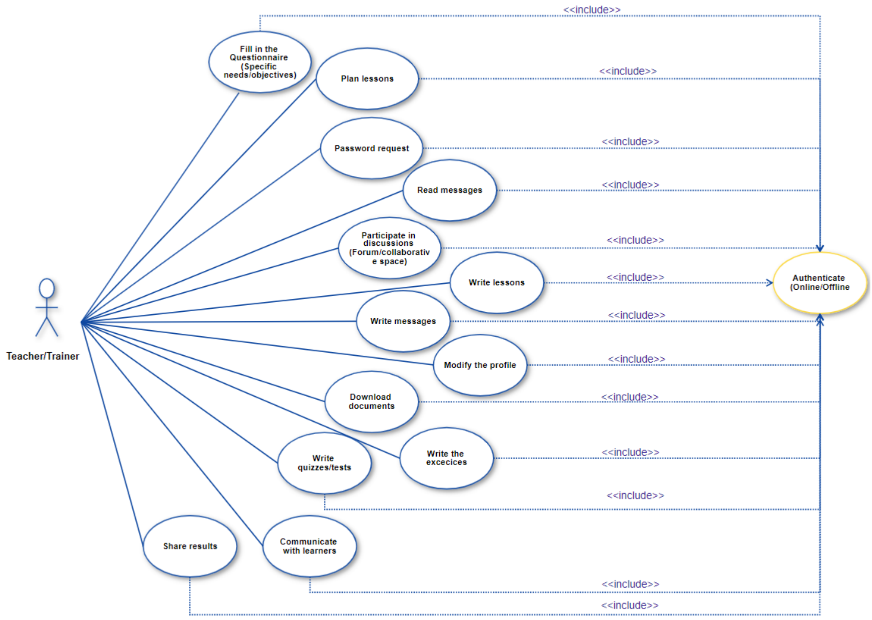

Fig. 5. Use case diagram for teachers/trainers

- **System:**
  As shown in Figure 6. The main role of this actor is to manage the platform, to collect to process, classify, adapt and store the collected data. The system also manages the queries and verifies the inputs given by the learners and teachers.

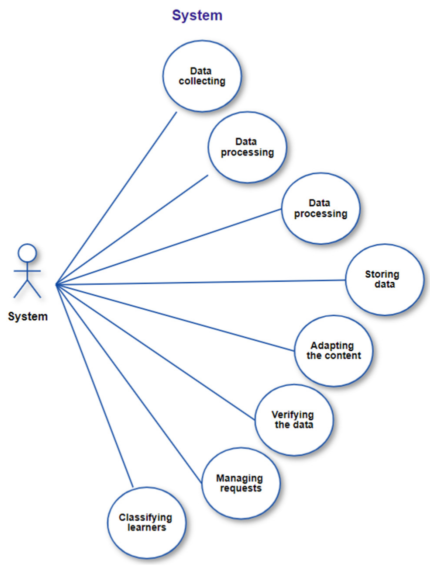

Fig. 6. Use case diagram for the system

4.2 The activity diagram

This diagram (Figure 7) describes the learning process of the learners according to the proposed approach:

Fig. 7. Learning process of the learners

5 Conclusion

The majority of online learning platforms focus on the classic actions in a learning process, such as consulting and following courses, participating in discussions, or even taking assessments and tests, but without taking into account the features that differentiate a learner apart from another, such as: learning styles, needs, preferences or objectives.

The integration of TIC into online learning systems, and more specifically the application of IA in such platform systems, enables the transformation of these platforms from a static to a dynamically customized and personalized version. In this paper, we presented the design and modeling of an adaptive learning system (ALSAI) on learning styles based on the 8 categories defined by FSLM. We considered three levels of adaptation (content, navigation and presentation) when designing our solution. We suggested a system design that relies primarily on artificial intelligence techniques such as deep learning, machine learning, and natural language processing.

In the near future, we plan to apply the proposed architecture in the Moodle LMS with data sample sizes and analyze the size effect; meanwhile, we also plan to choose the best machine learning and deep learning algorithms to apply for learning style detection, data classification, data prediction, etc. Then we will implement a chat bot and an automatic content translation system.

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