BUILDING AN ENGINEER'LEARNER CURRICULUM IN THE LIFELONG LEARNING CONTEXT – PLE AND AI SUPPORT

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ABSTRACT

With the emergence of IT technologies, the proliferation and diversification of learning tools, engineering schools have diversified their approaches, technics and educational resources in order to improve student-engineers performance. Thus, they have invested in the implementation of learning management systems (LMSs) which offer each learner the opportunity to personalize their learning. However, this personalization always depends on techno-pedagogical constraints and the educational institutions orientations. Considering the LMS personalization limits, the personal learning environments (PLEs) have come to allow learners to individually develop their learning environment by selecting the right resources and appropriate activities without taking into account institutional constraints. This concept is in vogue especially in the context of lifelong learning which is one of the recommendations of the sustainable development goals (SDGs). Generally, the setting up of such an environment is not based on techno-pedagogical foundations (Choice of objectives, selection of curriculums, appropriate activities and resources). As a result, we are faced with situations where the learning is not aligned with learner prerequisites or where the training layout did not align with the content and learner expectations. So, the question that arose is: how can the learner define his learning objectives, to build an appropriate curriculum and effectively follow his training? In this context, we propose an assisted PLE integrating a recommendations system. With the concepts of AI and based on a dynamic questionnaire, the learner can manage to design, implement and operate his/her curriculum and be master of his/her own training (CDIO Initiative). In addition, educational resources compatible with the curriculum will be recommended and the learner will have to select one according to his preferences and abilities. Our paper fits into an active-learning context (standard 8 - CDIO).

KEYWORDS

Lifelong Learning, Personalization, Personal Learning Environment (PLE), Recommendation System, Standard 8.

INTRODUCTION

Our contribution consists of defining an approach to assist engineering learners to build their own curriculum without pedagogy prior knowledge, and to take autonomous control of their learning. It promotes lifelong learning (alignment with the SDGs) and falls within the "active-Learning context" (CDIO standard 8) framework. Three phases characterize our approach: the first concerns assistance in the identification of learning objectives and the recommending appropriate curriculum(s), the second will be the assistance in the search for appropriate activities to the objectives already set, and the last will be responsible for maintaining and managing the learner's profile. In this paper, we will only focus on the first phase; the purpose is to build a learner's own curriculum. To do this, a consistent environment must be able to provide assistance to engineering learners to identify and choose their learning objectives. It's based on a dynamic questionnaire that takes into consideration the profiles and feedback learners information. An educational learning objective according to IMS-Learning Design standard (Koper, 2005) represented by a couple formed by a concept (C) and a learning level (N): C being a concept belonging to a domain ontology θ and N is one among the taxonomic levels in pedagogy (Bloom, Krathwohl, & Masia, 1984). Once the couple identified, our environment will be able to offer one or more curriculum(s) from a curricula corpus issue from different sources: educational and training institutions, and other resources (Cloud, OER, Moocs). A classification strategy using machine learning algorithms will then be applied to recommend appropriate curricula. Before going into the details, it would be appropriate to review the basic PLE theoretical foundations and the related work carried out in this area. We will first start by explaining the PLE concept, the PLE related work, and then we will present our assistance approach, subsequently our recommender system. We will end by presenting our experiment and the results obtained.

THEORETICAL FOUNDATIONS OF A PLE

Personal learning environment can be considered as a concept related to the use of learning technologies emphasizing learner ownership of tools and resources. The questions discussed are: How does the learner use technology to manage his/her learning? How is individual activity captured? What are the distinctive characteristics of personal learning environment? This study supports the idea that PLE can be considered as complex activity system using the activity theory (AT) framework (Bal, et al., 2023; Buchem, et al., 2011).

Activity Theory (AT) As An Integrated Framework

The PLE concept emphasizes the appropriation of tools and resources by learners. The view of learning as a mediation tool or collective activity is the basic principle of activity theory (Bal, et al., 2023; Kuhn, 2017; Sharples et al., 2005; Scanlon & Issroff, 2005). Activity Theory (AT) has been used as a framework for exploring pedagogical innovations and as a conceptual framework for analyzing and designing support systems for collaborative learning (Kuhn, 2017; Couros, 2010; Holton, 2007; Engeström, 1987; Vygotsky, 1980; Ogden & Richards, 1923, for mobile learning (Kuhn, 2017; Sharples, et al., 2005) and for learning technologies evaluation (Kuhn, 2017; Albero, 2001; Nardi, 1996).

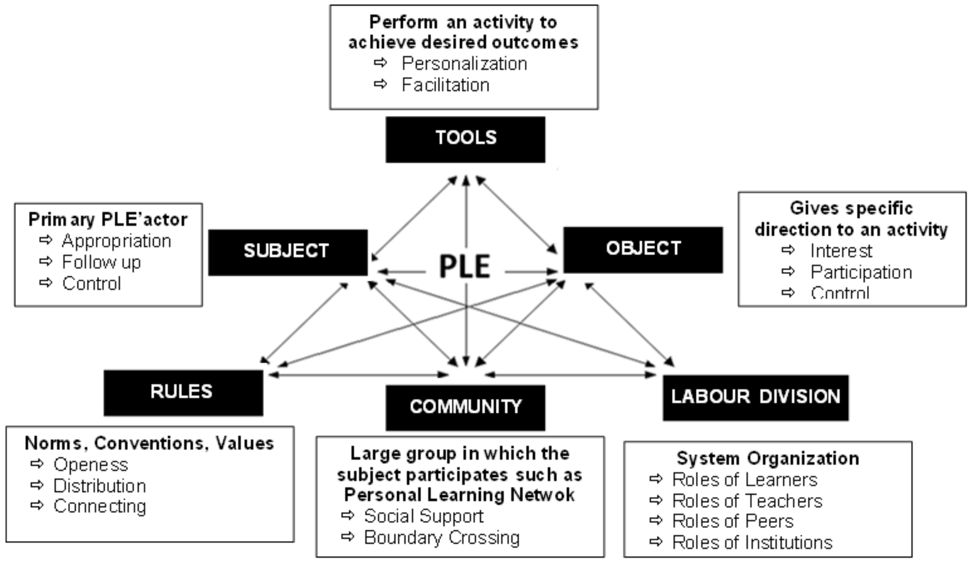

Figure 1. Summary of the PLE elements and its main dimensions

The study conducted by Buchem on a wide range of PLE publications, supports the idea that a PLE can be considered as a complex system of activities and can be analyzed using the framework of activity theory in order to describe its main components (Attwell, 2023; Bal, et al., 2023; Buchem, et al., 2011; Holton, 2007) (Figure 1).

PLE: Definition And Characteristics

"A PLE is a learner-centered approach, based on web technologies and allowing support, control and appropriation of learning independently of technical and institutional constraints" (Guettat, et al., 2024; Guettat & Farhat, 2017).

Based on the views of (Guettat, et al. 2024; Chatti, et al., 2021; Yen, et al., 2021; Göksel & Mutlu, 2021; Martindale, et al., 2019; Guettat & Farhat, 2017; Göksel, et al., 2016; Chatti, et al., 2011; Martindale & Dowdy, 2010; Drachsler, et al., 2008; Jafari, et al., 2006; Johnson, et al., 2006; Lubensky, 2008), PLEs should have the following characteristics:

- PLEs are open systems controlled by learners independently of the educational establishment.
- PLEs are customizable by learners.
- PLEs concentrate all the tools useful for the learner in a single environment.
- PLEs promote informal learning and lifelong learning.

As a result, it becomes clear that PLEs represent a turning point, from a model where learners simply consume information to one where learners become autonomous and create connections with a variety of resources that they select and curate themselves.

PLE Objectives

Although some of the fundamental needs of users of PLEs have not yet been clearly defined, two major objectives have nonetheless emerged in the literature: a PLE must be centered on learner and should enable lifelong learning (Attwell, 2023; Bal, et al., 2023; Buchem, et al., 2011). These two goals align with the Sustainable Development Goals (SDGs).

LIFELONG LEARNING

Lifelong Learning Context

Faced with the new landscape of educational technologies, learners continually face challenges in their learning. The speed of change as well as the growth of needs motivate learners to maintain the direction and extent of their lifelong learning. PLEs can be the appropriate solutions to these situations. These environments give learners the freedom to learn beyond course boundaries and institutional constraints, and customize their own learning environments before and during training. Additionally, e-Portfolios used by learners as a tool to trace their learning provide future employers an overview of the individual's learning history and results, skills and achievements. With PLEs, they allow learners to demonstrate their professional abilities in a continuous learning framework (Pan & Chen, 2023; Bal, et al., 2011; Chen, 2003).

Lifelong Learning Vision

The lifelong learning is the "Ongoing, voluntary, and self-motivated pursuit of knowledge for either personal or professional reasons. Therefore, it not only enhances social inclusion, active citizenship, and personal development, but also competitiveness and employability" (Leone, 2019; 2013), (Downes, 2019; 2018; 2010), (Guettat et al. 2024; Guettat & Farhat, 2013). The diffusing of the lifelong learning vision, signal the need for more personal, social and participatory approaches that support learners in becoming an active users and co-producers of his/her learning resources (Leone, 2019; 2013; European Commission, 2008). The emphasis on the shift from formal to informal e-learning through knowledge management and sharing has been placed, with particular attention to the PLE as learner-centered space. Nevertheless, the investigations are motivated by the many educational theories, implications and challenges that PLE concept has posed (Zhou, et al., 2020; Mcloughlin & Lee, 2010).

Learner Centered Learning

In a landscape marked by the evolution and emergence of educational technologies, and innovation in learning modes, models and methods, the learner is obliged to assume his/her tool choices to use and contributions intended to make in learning. Therefore, we need a learning model centered on learner, adaptable, flexible and specific, depending on the context, such that the learner will be able to control his/her individual choices in terms of the technologies to use by aligning them with his/her personal needs, interests, learning style, preferences and context. In this way, learner will know how to build and manage a personal and self-reflective learning environment rather than operating an environment constructed, managed and imposed by the teacher and/or institution (Attwell, 2023; 2007).

PLEs Roles In the Lifelong Learning

The PLEs give students the freedom to learn beyond course boundaries, and to personalize their own learning environment. They allow learners to learn anytime and anywhere. E-portfolios are currently used by learners in many education institutions as a tool to document and to reflect on their learning. They provide future employers with a snapshot of the learner’s learning history, learning achievements, and reflective practice. (Drajati, 2020; Renon, 2012).

Our Critical Analysis

Today's learning systems should break away from traditional learning methods because they can no longer satisfy everyone, especially with the perpetual evolution of technology. Other measures should be found to motivate learners to learn not only when they are in academic training, but also when they are independent. In our context, we are interested in lifelong engineering learners whose appropriation of learning can constitute a challenge for them. The solution that seems to be most appropriate is PLE. However, putting up personal learning environments requires solving a number of problems: How can the learner build his own personal curriculum? How does the learner profile will be maintained?

OUR ASSISTANCE APPROACH

Overview And Architecture

As part of our research in the field of PLE started in 2008, we have developed an innovative approach (Guettat, et al., 2024; Guettat, et al., 2013; Guettat & Farhat, 2017) allowing learners to build their personal learning environment, by building their own curriculums and choosing their appropriate learning activities. Such an approach will promote lifelong learning. To do this, we defined an architecture with three components: The “Curriculum builder”, the "Learning activities recommender" and the "Profile manager” (Figure 2).

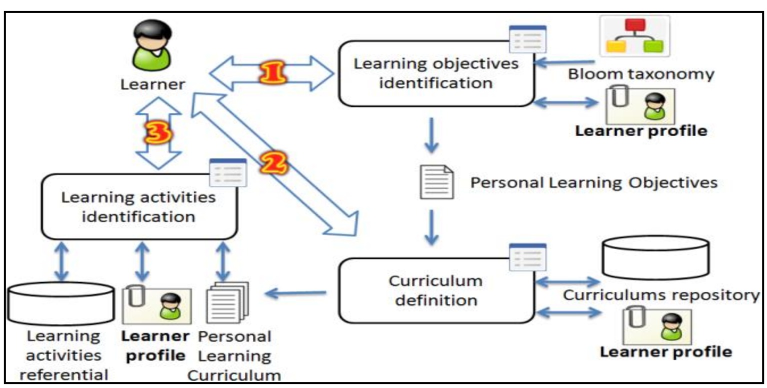

Figure 2. Overview of our Approach

Modeling Learner

Nowadays, several specifications aim to describe the learner in learning environments: IEEE PAPI learner (IEEE P1484.2.1/D8, 2002), IMS Reusable Definition of Competency or Educational Objective Specification (IMS-GLC-RDCEO, 2002), IMS Learner Information Package (IMS-GLC-LIP, 2005), IMS Learning Information Services (IMS-GLC-LIS, 2011) and IMS Learning Tools Interoperability (IMS-LTI, 2015). However, no study has been conducted to assess whether any of those specifications is appropriate to the PLEs. So, we are concerned by finding a specification useful in the case of PLE in general and for our approach in particular. We have identified a requirements set of learner model: personal information, previous knowledge, learning traces, learning objectives and learner preferences. Based on our study we demonstrate how the IEEE PAPI standard is suitable for the case of our approach and in general for the PLEs (Guettat & Farhat, 2014).

Assistance For Identifying Learning Objectives

Objective Identification Process

This component helps learners to choose their learning objectives. We start by offering them a list of concepts so they can choose one: e.g. Mechanics, Computer Science, Management, Mathematics or Medicine. Each Concept has a sub-concepts list. For the “Computer Science” concept we propose “Algorithmics”, “Office Automation”, “Programming”, “Databases”, “Computer Architecture”, “Operating Systems” and “Computer Networks”. The choice of objectives will be based on an interactive dialogue with the learner using a dynamic and user-friendly questionnaire (Figure 3).

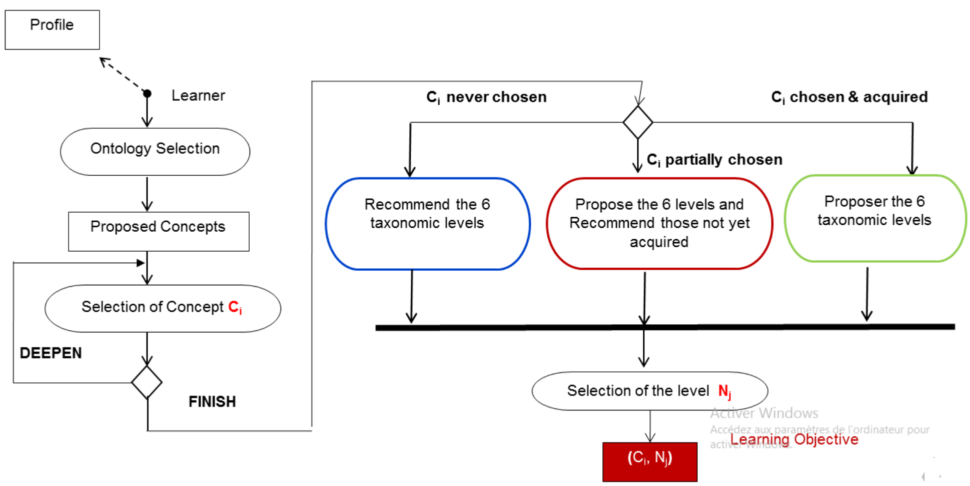

Figure 3. Objective identification diagram

Assistance For Curriculum Selection

Once the choice is made (concept C_i, taxonomic level N_j), the next step will consist of finding adapted curriculums. Two possible situations: The first, an exact match is found between the curriculum general objective and the learner learning objective and the second situation, we cannot find the right curriculum associated with the concept C_i.

First Situation: Exact Match Found

The selected curriculum will be used to identify the learning activities that must be accomplished by the learner. For example, we are looking for a course in “Computer Science” with a taxonomic level equals 2 (“Comprehension”); we found a bachelor's degree curriculum in computer science that matches. But in such a situation, several equivalent curricula may be found. Faced with such a situation, we will use concepts from Artificial Intelligence (AI) either to apply one of the classification algorithms to aggregate pieces of curriculums found, or to make a classification to recommend curricula to the learner (Di Ciaccio et al., 2012; Morineau et al., 1995). Based on our contribution which improved the IEEE-PAPI learner model in a PLE context, we are detecting significant and useful variables (features) for classification (Table 1).

Table 1. Sample of variables (Features)

Variable	Codification	Description
V1	LANG	Learner’s preferred Language: Fr, Ang, Ar, All, Esp.
V2	TYPF	Desired Type of Training: Quick, Medium, Long.
V3	NBUC	Uses Number of a given curriculum.
V4	NBAC	Number of completions on a given curriculum.
V5	RACC	Completion ratio on a given curriculum. (RACC = NBAC / NBUC)
V6	NBOB	Number of objectives in a given curriculum.
V7	NATC	Average of marks awarded by learners on a given curriculum.

In figure 4, we present a diagram describing the process of obtaining a personal curriculum.

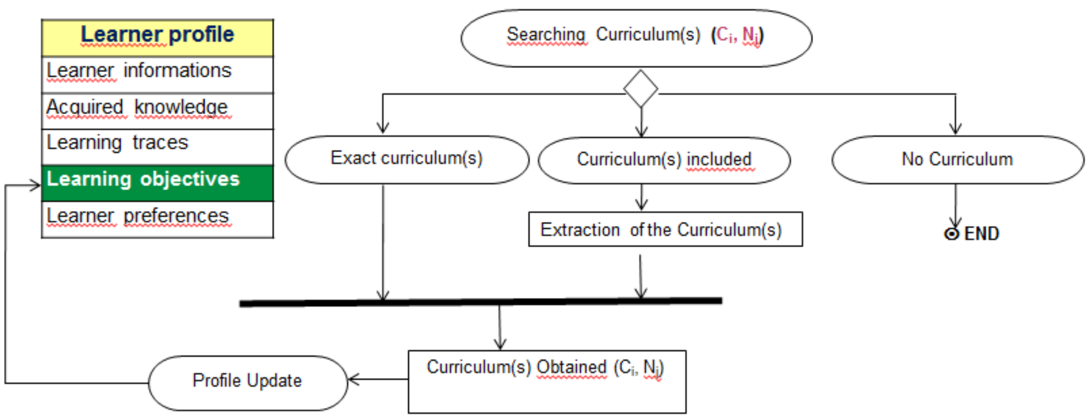

Figure 4. Curriculum selection diagram

Second Situation: Right Curriculum Not Found

For example, we are looking for training in BCNF (Boyce Codd Normal Form), but our system found nothing in the corpus. In this case, we need to go down the ontology and go to the “Normalization” node. It would then be necessary to work on the content of each curriculum concerning this node using its XML file and see if the associated block with the BCNF concept exists. The same thing here, we can find several equivalent blocks corresponding to our concept C_i and we must choose the most appropriate according to a classification strategy with always the same sample of variables.

EXPERIMENTATION AND RESULTS

In this section we will experiment a part of our approach (Identification of personal learning objectives and Curriculum recommendation). We have developed an assistant system, which allows any learner to use services offered without any technical or institutional constraints.

Web Architecture

This is web architecture with a client using a browser (e.g. Chrome) containing our system which will allow the learner to compose a personal curriculum and obtain the list of appropriate activities (Figure 5).

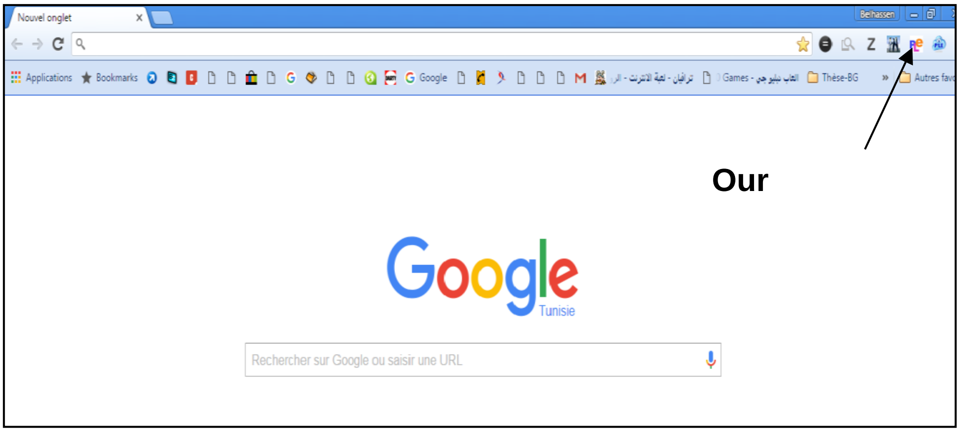

Figure 5. Our Assistant Interface

By clicking on the "PLE" Assistant, the learner could benefit from offered services system: identifying learning objectives assistant, curriculums recommender and activities recommender (Figure 6).

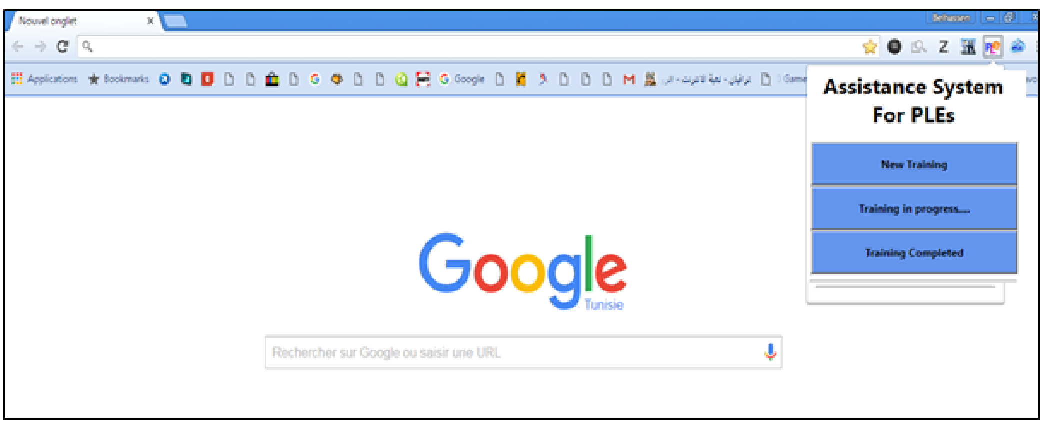

Figure 6. Services offered by our assistant

Assistance In Identifying Learning Objectives

Input Data Set

To experiment with this component, we had the following data sets:
- Set of learner profiles with different scenarios: Learner has never completed learning in a given concept, or has partially completed learning at given taxonomic levels, or has completely completed learning in a concept.
- Sample of learners requesting new learning curricula.
- A corpus of curriculums: Each curriculum concerns a well-defined concept.

First Situation: Learner wants to Learn "Databases" with Taxonomic Level 1

Our system will offer him all the curriculums (DB, 1) from our corpus. Which one will we recommend to him? Firstly, our system will make a filter by taking into consideration the learner requirements and his/her profile. After that, our system will execute the machine learning (ML) algorithm (Hierarchical classification algorithm). After notification of the variables, we obtained a curriculum list from our curriculum corpus including those dealing with "Databases" concept and the taxonomic levels. Given that the learner is interested in learning ("DB", 1), the system extracts from our corpus all the "DB" curriculums with taxonomic level equals 1 (Table 2).

Table 2. Extraction of curriculums related to (BD, 1)

Concept	Level	LANG	TYPF	NBOB	NBUC	NBAC	RACC	NATC
DB	1	1	1	2	1855	1000	0,539	06,20
DB	1	1	1	2	2500	1500	0,600	08,00
DB	1	0,66	0,66	3	1985	600	0,302	05,40
DB	1	0,5	1	2	750	300	0,400	04,80
DB	1	1	0,66	3	2265	1265	0,558	06,10
DB	1	1	0,33	5	4578	4000	0,874	08,70

Which curriculum(s) our system will recommend to learner? The ML algorithm will calculate the similarity distances; before, it converts all the values in the interval [0..1] (Table 3), and sorts the curriculums in ascending order according to d^2 rubric (Table 4).

Table 3.1 Sample of variables (Features) reduced to [0..1]

Concept	Niveau	LANG	TYPF	NBOB	NBUC	NBAC	RACC	NATC
DB	N1	1	1	0,00	0,19	0,13	0,539	0,70
DB	N1	1	1	0,00	0,26	0,19	0,600	0,90
DB	N1	0,66	0,66	0,33	0,21	0,08	0,302	0,61
DB	N1	0,5	1	0,00	0,08	0,04	0,400	0,54
DB	N1	1	0,66	0,33	0,23	0,16	0,558	0,69
DB	N1	1	0,33	1,00	0,47	0,50	0,874	0,98

Table 4. (d^2) sorted in ascending order by ML algorithm

Concept	Level	LANG	TYPF	NBOB	NBUC	NBAC	RACC	NATC	distance (d^2)
DB	N1	1	0,33	5	4578	4000	0,874	0,98	**00,979**
DB	N1	1	0,66	3	2265	1265	0,558	0,69	**02,060**
DB	N1	1	1	2	2500	1500	0,600	0,90	**02,296**
DB	N1	0,66	0,66	3	1985	600	0,302	0,61	**02,720**
DB	N1	0,5	1	2	750	300	0,400	0,54	**03,507**
DB	N1	1	1	2	1855	1000	0,539	0,70	**02,632**

As we noted, the curriculum with the lowest distance will be recommended, in our case, it is the curriculum (BD, N1) with distance $d^2=0.979$.

Second Situation: Learner having "DB" levels 1 & 2 wants a "BCNF" Level 1 Curriculum

Our system searched in the corpus but found nothing. He turned back to his domain ontology to go back one level. There, we found the concept "Normalization". We know well that the

BCNF concept is one of the normal form encountered in database courses, containing the "Normalization" chapter. We will therefore search all the Normalization curricula and detect the presence of the specific objective relating to the Boyce and Codd normal form. This means the system will work on the curriculum content (XML file) which its metadata is made up of the following sections: Concept, Level, Language, Training Type, Objective Number, Description, List of specific objectives.

To find the concept, the system will process the list of specific objectives contained in the XML files. As soon as we find concept_objs = "BCNF", it will select the corresponding curriculum. After processing on the already selected curriculums, we marked those which contain the concept "BCNF". Following this processing, we obtain the following four curriculums (Table 5):

Table 5. List of obtained curriculums

Concept	Level	LANG	TYPF	NBOB	NBUC	NBAC	RACC	NATC	distance (d^2)
Normalization	N3	0,66	0,66	0,33	0,47	0,19	0,396	0,98	**01,978**
Normalization	N1	0,5	0,66	0,33	0,15	0,13	0,821	0,67	**02,433**
Normalization	N1	1	1	0,00	0,13	0,13	0,977	0,46	**02,818**
Normalization	N4	0,66	0,66	0,33	0,00	0,00	0,000	0,00	**04,676**

The learner is looking for a BCNF curriculum with level = 1, our system recommends two but the one with d^2 = 0.2433 will be best recommended.

Results

Nearly, a hundred learners enrolled in the first year of IT engineering took part in the experiment. At the first, they passed a pre-test to divide them in two similar groups according to their level. After that, the two groups were invited for a test (in the same day: 2 hours). We asked the learners to solve the same exercise (about relational databases normalization) by creating their own PLE. Each learner in the control group has to build his/her own PLE and therefore to solve the given exercise. However, learners in the experimental group have access to our assistance system installed in their web browser. To evaluate the effectiveness of our approach, we measured the time and scores obtained by the group that used an unassisted PLE and the one who used an assisted PLE. We observed firstly the time of realization for the same activity to the two groups (Control and Experimental) (Table 6).

Table 6. Average of Times Activity

	Group	Number of Participants	Average (mn)	Standard deviation
Time	Control	50	**108,4000**	10,20022
	Experimental	50	**20,8333**	2,00144

The results confirm what we observed on the premises: the learner in the control group wasted a lot of time to find the appropriate resources to carry out the activity. We conclude that with an assisted PLE there is a gain in required learning time. On the other hand, we obtained the scores obtained by the two groups (Table 7).

Table 7. Average of Scores Activity

	Group	Number of Participants	Average (mn)	Standard deviation
Scores	Control	50	**7,85**	5,71086
	Experimental	50	**14,64**	1,64485

We find that the mean of the control group is 7.85 with a standard deviation of 5.7. On the other hand, the results obtained in the experimental group are much better. Indeed, the average score is 14.6 (almost the double) with a small standard deviation compared to that observed in the control group. This clearly shows that the use of an assisted PLE improves the learners ‘performance.

CONCLUSION & PERSPECTIVES

Nowadays, the use of Internet and especially the web is a part of our everyday activities. Web resources and tools are frequently used for learning. To learn anything the learner can look for the appropriate resources by asking peers in social medias or by using search engines for examples. The resources and tools chosen by the learner to learn can be considered as a PLE. In this paper we have presented a new approach to build assisted PLE for engineer-learner based on the artificial intelligence concepts (Machine Learning algorithms). The goal is to simplify the PLE building process and increasing the learning process efficiency.

To reach this goal, we began by discussing the limits of personalized learning environments, mainly because the institution generally imposes the choice of these environments, their content and the integrated educational tools. This situation can satisfy certain categories of learners but it can demotivate others, especially in the context of lifelong learning. From this came the concept of a personal learning environment (PLE).

We first distinguished between personalized environment and personal environment, we briefly reviewed the research work in PLE and noted that this concept has not reached the stage of maturity since those who have worked on this offer different visions and orientations. Even in the CDIO conferences, which started since 2005, and until 2023, this concept has not developed in the different participants acts and has never appeared in the different proceedings.

One of our contribution consists providing a clear definition of a PLE after an analysis and study of hundreds of scientific productions. The question that subsequently arose is how to find a method that will allow the learner to create their own PLE, because some who have tried to do so have sometimes missed their target because the tools chosen did not allow them to do so, to continue their learning and therefore they were not able to achieve their objective. Add to this their educational limitations, which prevent them from choosing an appropriate objective or curriculum.

Faced with this observation, we decided to develop an assistance approach, which will allow learners to build their learning curriculum in a context of lifelong learning, based on the concepts of PLE and AI.

So, we have developed a PLE assistance system and experimented it in a real situation. A significant sample of students enrolled in the first year of Engineer 'studies at Tunisia Higher School. They were divided in two groups: experimental and control. The results show that when using an assisted PLE learning time is shorter and scores are better than using a classical PLE.

For the perspectives, we are currently working on the problem of updating the learner profile when performing learning activities. In particular, we questioned the ability to evaluate success or failure when the learner accomplishes an activity. In a traditional e-learning system the activities are designed in a way to allow the collect of results by the system. In PLE we do not have such this control on activities.

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Syrine Karoui is a university teacher for 17 years. She joins ESPRIT School of Engineering (TUNISIA) in 2012. Her main teaching area are software engineering (Scrum Master certified), software architecture (ISAQB trainer), software testing (ISTQB certified trainer) and graph theory. She was the head of the Computer Science Department from 2018 to 2023. She's the head of the RDI team IRIS (Intelligent and Reliable Information Systems) and her research area include game theory, information security and artificial intelligence.

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