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Hybrid course instructional design for better practice of Learning Analytics

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Abstract

The adoption of hybrid and distance learning modes, supported by pedagogical and digital innovations, has favored the availability of large volumes of learning traces, resulting from learners' interactions with digital learning environments and services. These learning traces, in the form of digital footprints, represent the interactions that learners perform with learning content and systems, in the form of actions such as *logging on*, *navigating*, *consulting*, *completing*, *depositing*, *passing*, *providing answers*, *scoring*, etc., throughout their learning process. With the practice of *Learning Analytics* (LA), these traces are exploited using several different approaches, with the aim of fostering learners' success. However, educational organizations very often engage in the massive collection of both relevant and irrelevant or useless traces, requiring significant resources (time, human, material, etc.) and making the preparation and analysis phases linked to these data complex. In this paper, we propose the adoption of a learning object-oriented instructional design methodology with a structured approach to learning outcomes and learning paths, enabling better LA practice for monitoring learners' progression, participation, and performance. This approach allows for the collection of relevant traces, optimal preparation, and effective analysis of learning traces, to take better advantage of the benefits of *Learning Analytics* to improve and adapt learning processes and environments. This also makes it possible to better measure the impact of instructional design and Learning Analytics practice on the implementation of learning processes, to effectively evaluate learning outcomes, resources, activities, assessments, and learning paths. In this approach, it is demonstrated that the adoption of our design makes it possible to follow-up and evaluate for each learner his or her evolution in terms of learning outcomes, progression, participation, and performance across a course. It also demonstrates the potential for better management of learning processes, learning paths, quality assessment of learning content, and learning path recommendations. This approach provides a more global understanding of this information across a set of courses, with a view to tracking learners' progress through a training program.

Keywords: Instructional design, Learning Analytics, Learning objects, Learning outcomes, Learning paths, Hybridization, Distance learning

I. Introduction

Pedagogical and digital innovations have completely changed the way we teach and learn, by making education accessible to the wide public without constraints of physical space, time,

place, or health restrictions (e.g., Covid-19) with hybrid or distance learning to ensure continuity of pedagogical activities.

To facilitate the production of teaching adapted to learners' needs, and ensure that the intended pedagogical objectives are achieved, educational organizations are adopting solutions based on instructional design models. These models are defined as a set of systematic methods within a prescriptive logic for the design and development of learning content and systems [1].

In this context of pedagogical design increasingly supported by technology, learners leave behind learning traces (digital footprints) allowing us to consider that *"Every deposit, click or share is a learner shouting out his likes and dislikes. These actions are the frowns, smiles and crossed arms of the classroom, simply in digital form"* [2]. Therefore, Learning Analytics (LA), the practice of collecting and analyzing learning traces to provide answers to the needs of understanding, improving, and optimizing learning, as well as learning systems [3], has become an emerging trend within educational organizations.

However, traditional course formats often offer little opportunity to exploit the full potential of LA. Indeed, the exploitation of traces is often done a posteriori, once the data has been collected, without necessarily taking advantage of the relationships between learning resources and learning outcomes in terms of knowledge or skills. In addition, with the constant innovations in the way teaching is carried out, it is necessary to rethink and transform the course design model to enable educational organizations, teachers, and learners to make the most of the benefits offered by the practice of LA.

In this paper, we propose a methodology for designing hybrid courses, based on an approach that promotes better LA practices. This approach enables teachers to design their hybrid courses by adopting a pedagogical design that anticipates and facilitates the work of collecting, analyzing and interpreting learning traces. It also encourages the integration of the learning outcomes dimension right from the course design phase, to make the most of learning outcomes and effectively monitor learners during the learning process.

II. Problem statement

Pedagogical and digital transformations have encouraged a democratization of access to knowledge and facilitated the acquisition of skills, with the emergence of enormous solutions for improving, adapting, optimizing, and personalizing learning through the practice of Learning Analytics. However, it is difficult to provide answers to these evolving needs for an education that is open to a wide range of different profiles, expectations, and rhythms, with a large quantity of educational content available (Internet, Wikipedia, YouTube, learned societies, electronic articles and books, MOOCs, etc.) and heterogeneous in format and content. This makes it difficult to effectively exploit pedagogical content in relation to learning outcomes and learning paths to better guide learners' progress and facilitate the teacher's mission. This lack of relationship also makes it difficult to obtain precise, measurable information on the use of learning content and the results achieved in terms of learning outcomes. This lack of information makes it complex to better practice Learning Analytics for effective monitoring of learner progression, participation and performance based on the learning traces left by learners during the learning process. In addition, without preliminary identification of the relevant data to be collected, educational organizations can engage in massive collection of traces that are both relevant and irrelevant or useless, requiring significant

resources (time, human, material, etc.) and making the phases of collection, preparation, and analysis of learning traces more complex.

III. Literature review

Instructional design frameworks are based on a set of systematic methods that take a prescriptive approach to the design and development of educational solutions [1]. They facilitate the production of a course while enabling adaptation to the specific and evolving needs of learners with different prerequisites, objectives and learning paths, and ensuring that the intended pedagogical objectives are achieved. Several theoretical frameworks following different approaches have been developed, such as the models proposed by [4, 5, 6, 7]. There are also the ADDIE (*Analysis, Design, Development, Implementation and Evaluation*) [8] and the *Successive Approximation Model* (SAM) [9] models, which define a set of procedures for developing a learning system. The MISA method is a *Learning Systems Engineering Method* that enables learning systems to be designed based on a combination of pedagogical engineering and theoretical knowledge through a systematic and cognitive process [10]. The *Activity Based Curriculum* (ABC) *Learning Design* (LD) model is an instructional design methodology, guided by learning types and the sequencing of face-to-face and online learning activities according to learning outcomes, by creating a storyboard [11].

The common characteristic of all these frameworks is that they provide a guided methodology for the design and creation of pedagogical content, even though they are not specifically adapted to the pedagogical design of a hybrid and/or distance course. Nowadays, the instructional design process is increasingly supported by technology, enabling finer granularity of course content for flexible, adaptive learning. To ensure this, it is necessary to consider the LA dimension from the instructional design phase onwards, to promote the effective identification, collection, and analysis of relevant learning data to foster better LA practice. This also makes it possible to better measure the impact of instructional design, integrating the analysis of trace data from different learning processes to effectively evaluate learning outcomes, resources, activities, assessments and learning paths.

In this section presents a review of the literature on instructional design and Learning Analytics alignment methodologies for improving, adapting, personalizing, and optimizing learning to enhance learner success. There are several works that propose solutions for aligning the pedagogical design of an online or hybrid course with the practice of Learning Analytics, following different approaches.

Yassine et al [12] propose a framework based on the use of the open-source Learning Management System (LMS) Moodle, student interactions with the LMS and learning outcomes for the creation of a Learning Analytics tool. The proposed model is based on fundamental analytical processes involving (1) *the identification of LMS activities required to assess learning outcomes*, (2) *the association of these identified activities with course learning outcomes*, (3) *the analysis of student activities and the assessment of learning outcomes*, and (4) *the visualization of information*. The particularity of this model is that it makes it possible to evaluate and predict student performance and results based on the specific learning outcomes already identified in a course.

Nguyen et al. [13] propose an instructional design methodology that integrates Learning Analytics into the design of learning activities. The development of this solution is based on

models and concepts linked to the fields of LA, instructional design, and information systems. The authors develop a methodology that serves as a guideline for an LA practice that supports the instructional design process.

Aljohani et al. [14] develop an integrated approach to LA practice, adapted to a course with a learning analysis dashboard for students based on the use of the Blackboard LMS. This model is based on a four-level process of (1) *instructor (teacher, students, and learning materials)*, (2) *data (data collection, storage, and retrieval)*, (3) *data analysis (data analysis techniques)* and (4) *presentation (dashboard)*. This makes it possible to create a personalized dashboard for each student, with indicators measured based on data relating to access to the LMS platform, discussion forum activities and quiz results.

Erkan Er et al. [15] develop a methodology for aligning instructional design and Learning Analytics in the context of a MOOC, involving teachers in the design of a Learning Analytics system. The implementation of this model is based on three main steps: (1) *identification of the instructional design methodology, the instructional objectives and the tasks to be predicted*, (2) *construction and comparison of predictive models*, and (3) *evaluation of the impact of the instructional design*. In this work, the authors propose an LA practice based on two approaches, one of which is specifically guided by objectives and instructional design, and the other with generic functionalities.

The literature review shows that the model proposed by *Yassine et al.* [12] enables identification of the necessary traces and alignment between activities and learning outcomes but does not provide a strategy for effective collection and analysis of learning traces. The methodology of *Nguyen et al.* [13] is more oriented towards an approach based on transforming the way AL systems are designed and developed to better support the instructional design process. However, these two works also present certain limitations linked to a lack of application of methodology, additional evaluations, and validation. The proposal by *Aljohani et al.* [14] focuses more on improving student performance in a course than on aligning instructional design with LA practice and integrating learning trace analysis methodologies. The framework proposed by *Erkan Er et al.* [15] only provides a guided design of the learning content required for better alignment of instructional design with LA practice.

The analysis of these works shows that they do not allow us to specify and better manage learning processes, or to reduce the complexity of implementing LA solutions. Moreover, they offer little possibility of providing progressive evaluations and recommendations (feedbacks) to the learner or teacher during the learning process. To successfully improve, adapt, personalize, and optimize learning based on an alignment between the pedagogical design of an online or hybrid course and LA, it is necessary to consider certain indispensable criteria, which can be summarized around five points in the table below.

Category	Criteria	Description
Pedagogy	Guided design of learning content	Provide a methodology for the design, development and implementation of pedagogical content that promotes better practice of LA.

	Learning outcomes-oriented approach	Enable monitoring of the learner's progress in terms of knowledge or competence acquisition.
	Definition of learning paths	Define a sequence of mandatory or alternative learning content based on prerequisites and learning outcomes.
Digital	Integration of learning traces analysis	Integrate the LA practice dimension from the instructional design.
	Integration of ICTE	Adopt a model for integrating ICTE that promotes a better alliance between technology (LA) and people (instructional design) for learning.

Table 1: Criteria for aligning instructional design and Learning Analytics practice

IV. Methodology

For better LA practice, it is essential to rethink the way teachers design their courses, especially when it comes to integrating the enormous possibilities offered by asynchronous hybridization and the piloting offered by LA. To do so, we propose a methodology based on the notion of pedagogical design, which is intended as a course design approach based on the use of a process based on 1) *identification of learning outcomes*, 2) *definition of learning objects*, 3) *relationship between learning objects and learning outcomes*, 4) *definition of learning paths*, 5) *identification of traces and analysis methodologies in an approach guided by pedagogical design*, and 6) *integration of a collaborative construction and continuous improvement methodology*.

IV.1 Identification of learning outcomes (LOs)

This step consists of identifying the learning outcomes expected of learners at the end of an education program, which will serve as a basis for guiding the instructional design. A learning outcome is defined by the European Qualification Framework (EQF) for lifelong learning as: "*a statement of what a learner knows, understands and is able to do at the end of a learning process*" [16] (see figure 1a). The *Commission des Titres d'Ingénieur (CTI)* proposes the following definition: "*...learning outcomes are expressed in terms of knowledge, skills, or competences, whether general (necessary for any engineer) or specific (related to the field or speciality)*" [17]. However, once the learning outcomes (LOs) have been identified, it is necessary to move on to expressing the LO explicitly in terms of the learning outcome expected from the learner. There are several approaches to expressing LOs. We will follow the model proposed by *BLOOM's* taxonomy [18], and in particular the cognitive model defined on the basis of 6 levels: *Knowledge, Comprehension, Application, Analysis, Synthesis* and *Evaluation*.

A learning outcome is associated with a competency that can be a aptitude, skill, knowledge, ability, etc. and it can become a learning income (prerequisite) for acquiring new knowledge or skills. The competency may comprise *Micro Competencies* or belong to a *Macro Competency* (see figure 1b).

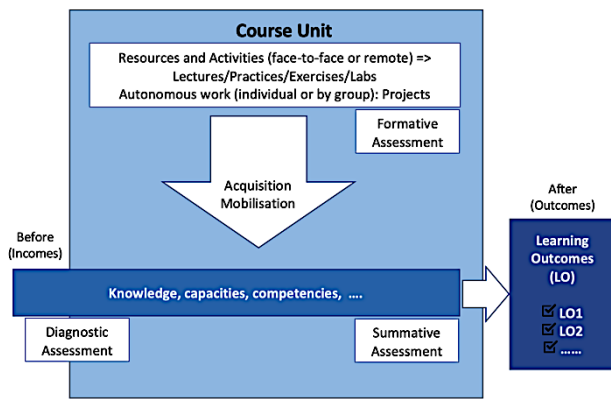


Figure 1a: Learning Outcomes specification

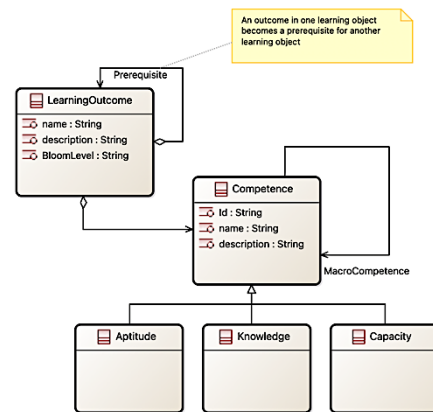


Figure 1b: Learning Outcomes class diagram

IV.2 Definition of Learning Objects (LO)

Learning objects represent combinations of resources, activities, and assessments to be implemented to achieve expected outcomes (see Figure 2). According to Cisco Systems, "a learning object is a collection of content elements, practice elements, and assessment elements that are combined based on a single learning outcome" [19]. Canada's Centre for Innovation in Teaching and Learning (CITL) defines a learning object as "a digital and open educational resource created to facilitate a learning process. The concepts of learning and reuse are central to this resource. Each learning object will have an instructional design" [20].

Based on these different definitions, a learning object could be composed by a set of elements consisting of:

- Learning resources (video, document, audio or podcast, web page, etc.).
- Learning activities (homework assignments, workshops, forums, etc.).
- And diagnostic, formative, or summative assessment activities (quiz, exam, etc.).

It is important to underline that when using a Learning Management System, it is not always obvious to differentiate the constituent elements of a learning object. However, there are several technical solutions (SCORM, H5P, etc.) capable of providing the necessary encapsulation for LO (see figure 2a), e.g., the realization of an interactive H5P video [21] would allow the inclusion of questions to have all the elements of a learning object: the content of a resource (the video), the learning activities (questions/answers) and the assessment (comparison of the inputs with a base of expected answers).

The *learning resources*, *learning activities* and *assessment activities* that make up the *learning objects* each provide information about its *duration*, *type*, *progression*, and *universal location* (see figure 2b).

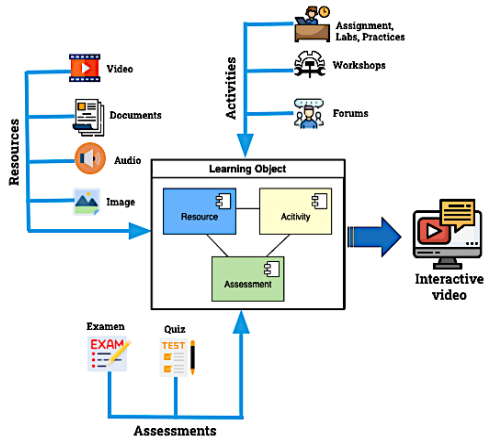


Figure 2a: Learning Object composition

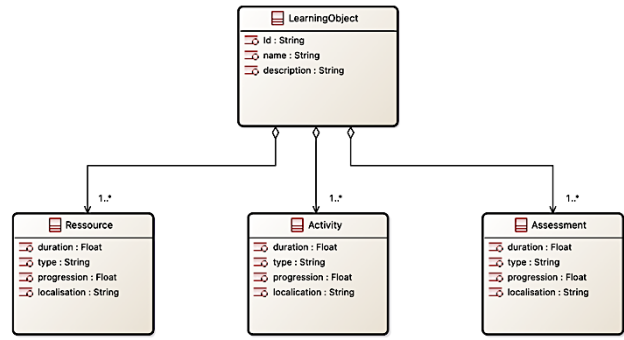


Figure 2b: Learning Object class diagram

IV.3 Relationship between learning objects and learning outcomes

A learning object aims to achieve a learning outcome. In other words, the resources offer the possibility of conveying an idea, a concept, or a method of solving a problem, for example. The activities included in the object make it possible to mobilize these ideas or concepts to facilitate their understanding or their application in the resolution of a problem. Finally, the assessment allows to validate the acquisition of knowledge or skills, i.e., to validate the learning outcome (see Figures 3a and 3b). In our proposal, to simplify the pedagogical design, we consider that an object must allow to validate (totally or partially) a single learning outcome (or sub-learning outcome).

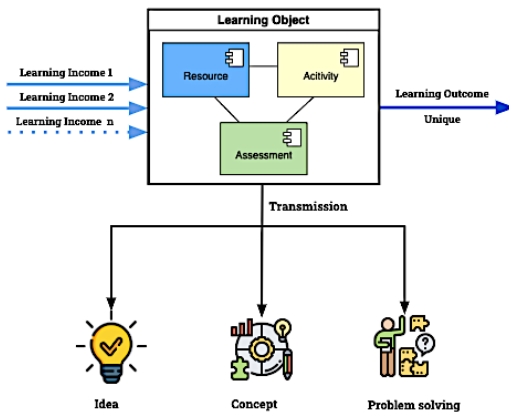


Figure 3a: Learning object and outcome relationship

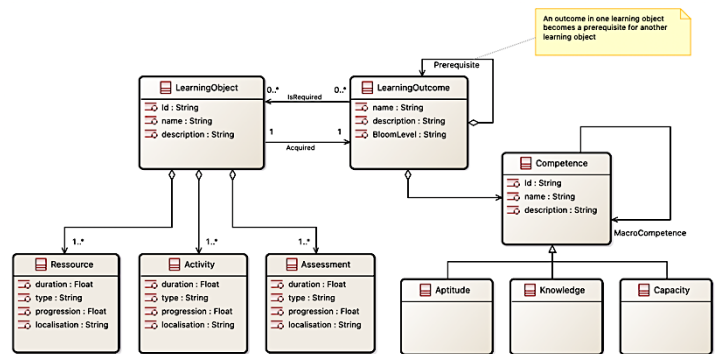


Figure 3b: Learning object and outcome class diagram

Each learning object is associated with certain predefined rules that allow for better control of the learner's progress based on *learning incomes* (prerequisites) and *learning outcomes*. This level of granularity facilitates the sequencing or parallelization of learning objects and allows the identification of learning paths.

IV.4 Definition of learning paths (LP)

A learning path can be defined as the route taken by a learner through access to available learning objects, active participation in the learning process to mobilize and apply knowledge, and assessments that validate learning outcomes. According to [22], "the learning path is described as the trajectory chosen by a learner through a series of (usually) e-learning activities, which allows him/her to progressively acquire knowledge". A learning path is very similar to a learning object, the difference being that a learning object targets only one learning outcome and a learning path can target several (see figures 4a and 4b). In short, a learning pathway can be thought of as a composite learning object, consisting of several learning objects that can be staged in various combinations (a sequence of mandatory objects, a set of alternative objects, or a mixture of mandatory and alternative objects).

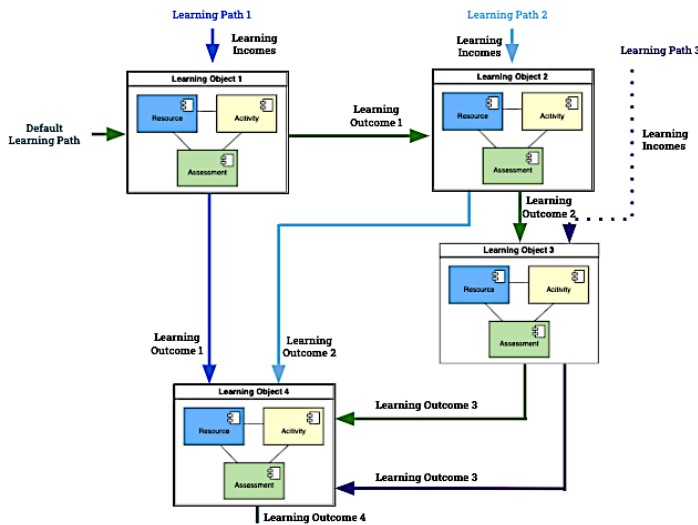


Figure 4a: Learning path definition

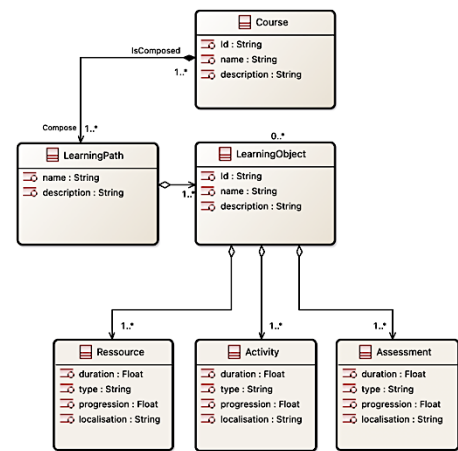


Figure 4b: Learning path class diagram

In a learning path, each learning object (LO) can be associated with certain predefined rules that allow better control of the learner's progress based on prerequisites and learning outcomes. The access to a LO can be conditioned by the fulfillment of one or more learning prerequisites allowing the learner to have the basic knowledge and/or skills necessary for a better understanding or appropriation of the LO, as well as its associated learning outcome. With the sequencing of learning objects, an asset in one learning object can become a prerequisite for another learning object. It is through the prerequisites and targeted learning outcomes that learning paths can be defined as a sequence of mandatory or alternative objects. In this learning object-oriented course design approach, a *course* is composed of *learning paths* which are constituted by *learning objects*.

IV.5 Integration of a collective construction and continuous improvement methodology

With this pedagogical design, learning objects and learning paths can be implemented by the pedagogical team to meet the expected learning outcomes. Moreover, this pedagogical design allows to build a bridge between the technological and pedagogical to provide a synthesis work integrating the contributions of the fields summarized in Table 2. of the technical, pedagogical, economic, ergonomic, and organizational domains:

Domains	Description of the contribution
Technical	A pragmatic approach that refers to the management of a training project in all its aspects and to the coordination of the work of several specialists.
Pedagogical	In-depth reflection on learning processes and requirements
Economic	Notion of reusable learning objects and learning outcomes (competencies) facilitating the implementation of a competency-based approach.
Ergonomic	Better visibility on the learning paths followed and a flexible tool that is easily transferable within the educational teams.
Organizational	A collaborative approach that allows the expertise of the different specialists involved in the design of a training system to be valued; the sharing and ease of reusing learning objects, knowledge, skills, and teaching/learning experiences.

Table 2: Areas of contribution of instructional design

V. Learning Analytics practice driven by instructional design

The application of this instructional design allows an easy identification of the traces (events) to be captured on learning objects, learning paths and learning outcomes, as well as an easy definition of indicators for a better practice of the four levels of analysis (*Description, Diagnosis, Prediction and Prescription*) of learning traces.

V.1 Event Pattern specification for Learning Analytics.

The implementation of our instructional design is based on the use of standard learning environments (LMS such as *Moodle* or *Canvas*) offers an excellent opportunity to identify in a simple and uniform way the traces that will be collected on learning objects, learning paths and learning outcomes. Thus, learning objects and learning paths will form a bridge between instructional design and learning analytics. To define a standard and homogeneous framework for the implementation of LA, we need to precisely state our definition of learning traces (learning events), which can be described as data sets that should include at least the following (see figure 6):

- **Who:** identification of the actor who is at the origin of each trace?
- **What:** action performed by the actor.
- **When:** date and time of the generation of each trace.
- **Where:** learning object (resource, activity, or assessment) on which the actor performed the action.

The learning traces collected constitute all the traces of interactions carried out by the learner on the learning objects in the form of actions of *connection, navigation, consultation, completion, submission, success, answers provided, score obtained*, etc. which are integrated into the composition of the learning object.

Based on this definition, the traces collected around each learning object will allow us to measure the impact of the learner's effort in validating the learning outcomes associated with the objects and learning paths.

Learning Traces

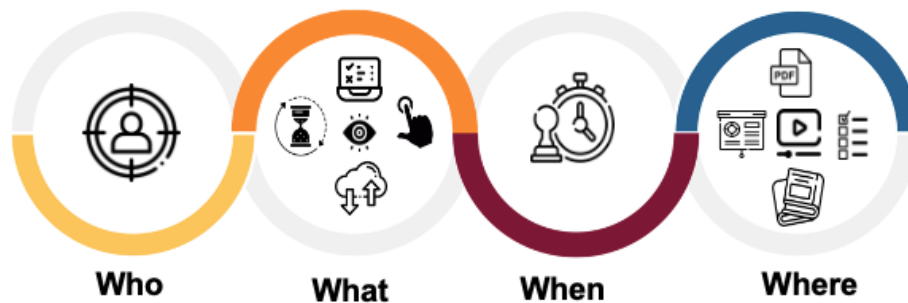


Figure 6: Learning traces definition

V.2 Association of learning traces sensors with the resources, activities, and assessments of learning objects.

The implementation of our instructional design approach allows the specification of sensors that need to be deployed to efficiently collect learning traces to enable effective analyses. The sensors of learning traces are associated with the resources, activities, and assessments of a learning object. This ensures that the instructional design elements (learning object) are linked to the trace sensors as early as the instructional design phase (see table 3). The explicit identification of the traces from the beginning avoids a massive and useless collection of irrelevant data to make the trace processing and analysis phases less complex (generally considered as time-consuming activities).

Learning traces sensors	Resource, activity, assessment, and learning objects			
	<i>Resource</i>	<i>Activity</i>	<i>Assessment</i>	<i>Learning Object</i>
<i>navigated-in</i>	✓	✓	✓	✓
<i>viewed</i>	✓	✓	✓	✓
<i>marked-completion</i>	✓	✓	✓	✓
<i>completed</i>	✓	✓	✓	✓
<i>submitted</i>		✓	✓	✓
<i>answered</i>		✓	✓	✓
<i>scored</i>		✓	✓	✓

<i>graded</i>			✓	✓
<i>passed</i>		✓	✓	✓

Table 3: Association of learning traces with resources, activities, assessments of learning objects

V.3 Définition and calculation of Learning Analytics indicators

To ensure accurate monitoring of learning outcomes, it is essential to identify the data to be collected (trace collectors) that can be easily associated with the definition of *progression*, *participation*, and *performance* indicators (see table 4). This information could be used to calculate indicators based on actions resulting from the learner's possible interactions with the course's learning objects (see table 5).

Indicator	Definition
Progression	Indicator of learner progress in the course content (learning objects) made available, defined according to the connection, navigation, consultation, and disconnection actions performed by the learner on the platform and on the learning objects.
Participation	Indicator of learner participation in the course, defined based on actions related to completion, indication of completion, success, as well as results and assessments, performed by the learner on the learning objects.
Performance	Indicator of learner performance on questions related to the activities and assessments embedded in the learning objects, obtained based on the actions of submitting correct answers, performed by the learner on the learning objects.

Table 4: Definition of Learning Analytics indicators

Indicator	Definition
Progression	Ratio of the number of completed learning objects to the number of learning objects available in the course.
Participation	Ratio between the number of interaction actions performed on the learning objects and the number of actions available in the course.
Performance	Ratio between the cumulative score obtained in the interaction actions and the maximum possible score.

Table 5: Calculation of Learning Analytics indicators

With this instructional design approach, learning objects and learning paths enable learning through interactions with learners. The latter promote the generation and identification of

traces or digital footprints of an event or action performed during the learning process. Adopting this design provides a continuous improvement approach that would guide the identification, collection, and analysis of learning traces to better leverage LA and support decision-making at least three levels:

Level	Decision-making support
Operational	To ensure the progression of each learner, by proposing learning objects that adapt to his or her pace and the use of descriptive indicators to observe his or her progress.
Management	Analyze a portion of the learner's performance across different courses taken in the same period and identify overall trends and the need to recommend specific learning objects to meet certain prerequisites. Also, the overall management of the training program, the possibilities to reschedule or even share the workload of learners and teachers, to increase and promote success.
Strategic	To be able to carry out a qualitative evaluation of the training, to be able to better understand the profile of the learners and to know if it is necessary to also evolve the quality of the learning objects and the effort of the activities in the acquisition of knowledge and skills.

Table 6: Levels of decision-making support

Figure 7a below illustrates a conceptual representation of the entities, as well as their relationships and compositions of our learning object-oriented course design methodology for a better exploitation of learning data. In this approach, a *course* is composed by *learning paths* constituted by *learning objects* which are a set of *learning resources*, *learning activities* and *assessment activities* each providing information about its duration, type, progression, and universal location (URL). Each learning object is associated with certain predefined rules that allow better control of the learner's progress based on *learning incomes (prerequisites)* and *learning outcomes*. This level of granularity facilitates the sequencing of learning objects and allows the identification of learning paths.

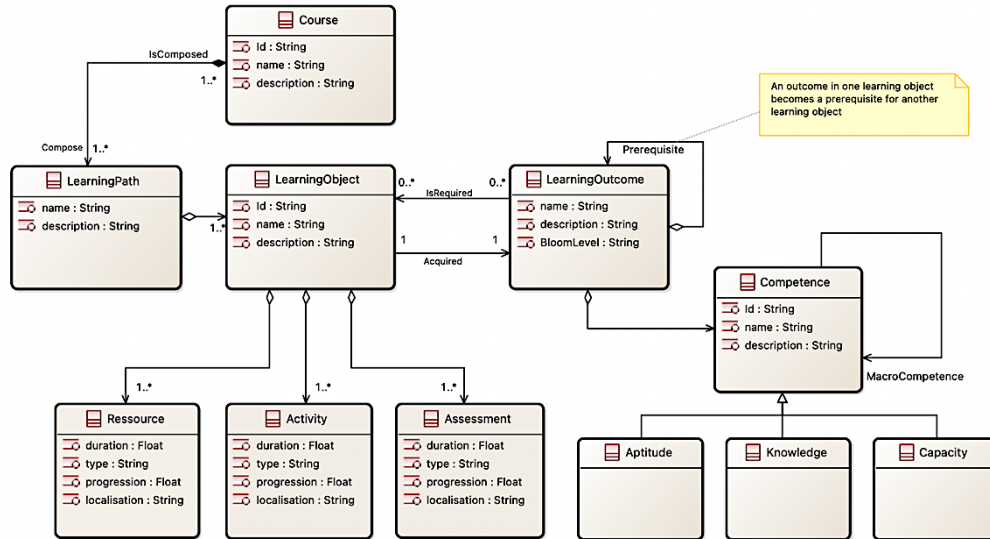


Figure 7a: Instructional design global class diagram

The fine granularity integrated in the instructional design provides precise and measurable information on the *learning objects*, and *ressources*, *activities* and *assessments* used, as well as the actions performed and their execution conditions. This information can also be used for *Learning Analytics* since it is possible to insert sensors to collect learning data and thus process the data and produce appropriate analyses (see figure 7b).

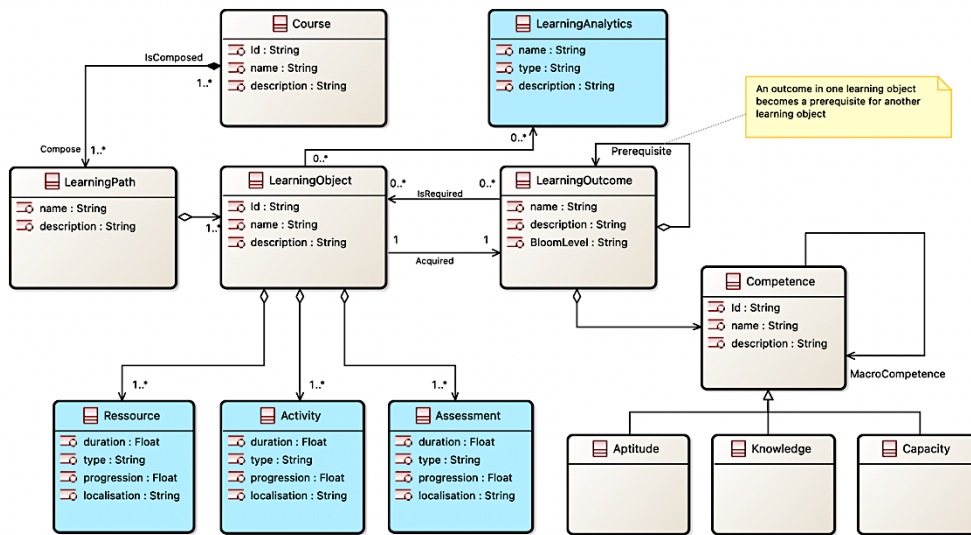


Figure 7b: Learning Analytics dimension integrated in instructional design

VI. Instructional design implementation

The instructional design methodology proposed in this article was adopted in the design and implementation of a *Small Private Online Course* (SPOC) for higher education teachers. The learners were composed of more than two hundred staff members who were part of a consortium of twelve French universities participating in the [HyPE-13](#) project (ANR-PIA3:

Hybrider et Partager les Enseignements). The objective of this SPOC was to train teachers in the design of hybrid courses, integrating the analysis of digital learning traces. It also aimed to present the foundations of methods and tools for analyzing and interpreting digital learning data to help teachers provide personalized support to their students. In addition, this SPOC offered a general introduction to Learning Analytics (LA) to raise teachers' awareness and provide a methodological framework for designing courses with LA integration. The SPOC consists of six learning paths (LP), each of which is composed of at least five learning objects (LO). The SPOC was launched in June 2021 and offered six hours of training, including four hours of asynchronous learning activities and two hours of synchronous learning activities, in a workshop format. The target audience was teachers, training managers and university staff. This scenario allowed us not only to deploy the methodology in a context, with a larger number of participants and a more demanding and experienced audience, but also to use it as a tool for the dissemination of the methodology itself as well as its evaluation. Indeed, the learning outcome and the learning objects themselves contain the proposed methodology and the feedback from the participants was therefore an excellent opportunity to disseminate, evaluate and validate it.

SPOC title	General Introduction to Learning Analytics
Duration	6 hours
Target audience	Higher education teachers
Language of instruction	French
Number of participants	+200 participants
Teaching method	Distance learning in synchronous and asynchronous mode
Number of macro learning outcomes	2
Number of micro learning outcomes	8
Number of learning objects	40
Number of learning path	6

Tableau 7: SPOC information summary

The application of this design allows an easy identification of the traces to be captured on learning objects, learning paths and learning outcomes, as well as an easy definition of indicators for a better practice of the four levels of learning traces analysis. The results obtained showed that the proposed pedagogical design methodology ensured a strong link between pedagogical and digital innovations. Moreover, the connection between pedagogical design and learning traces sensors from the design phase of a course, allowed to efficiently

guide the construction of learning paths while avoiding a massive and useless collection of irrelevant data to make the processing and analysis phases of the traces less complex. The pedagogical and digital transformations must explicitly integrate the acquisition of knowledge and skills to ensure a better consideration of the needs for improvement, adaptation, optimization, and personalization of learning open to a wide range of profiles, expectations, and different paces.

With the adoption of our approach, the collection of learning traces is limited to only those data relevant to the objective of effective LA practice for better consideration of data respect and confidentiality. Moreover, it allows to optimize the resources needed for the data collection, preparation, and analysis phases for an efficient exploitation of the LA contributions.

Within the framework of the SPOC, it is a team composed of a teacher, a doctoral student and a technical-pedagogical engineer. This type of design, which can be used for face-to-face and synchronous courses, requires the use of IT technologies to offer personalized and efficient support to students following a distance and asynchronous training. Moreover, this instructional design allows to build a bridge between the technological and the pedagogical ecosystems to provide a synthesis work integrating the contributions of the technical, pedagogical, economic, ergonomic, and organizational fields. However, at this stage of the implementation of our pedagogical design methodology, we have mainly focused on the theoretical dimension of learning that mainly promotes the acquisition of knowledge, as it occurs in a lecture. Indeed, most of the learning objects developed and evaluated were oriented towards replacing traditional courses according to flipped classroom modalities. Problem-based, project-based, and challenge-based pedagogy would require another type of more advanced dynamic objects, probably shared between learners (in the case of a collaborative project). This type of object could be built based on the development of virtual work environments, which would allow to accompany learners in the acquisition and application of skills, and at the same time to provide the necessary learning traces to ensure the corresponding follow-up and remediation plans.

Moreover, in the implementation of our proposal, the LMS is the only source of learning traces from the learning environment. However, solutions to overcome these limitations, as well as a more global evaluation within the framework of a massive deployment of the solution on a university scale are envisaged. The integration of the practical learning activities-oriented dimension could allow the design of resources, activities and assessments including practical work in the basic granularity level (activities, resources or assessment), as well as the intermediate level (learning object) and the highest level (learning path). It would also be interesting to be able to integrate new interaction actions into the object encapsulation, such as the use of discussion forums, which would allow for more asynchronous and collective exchanges.

VII. Results

This section presents the results obtained from various implementations of Learning Analytics solutions guided by the application of our instructional design methodology for efficient monitoring and assessment of learners.

VII.1 Monitoring and evaluating learner progress in terms of learning outcomes

To monitor and evaluate learning outcomes, the *Competency tool* of the *Moodle LMS* was implemented and the plugin *Monitoring of learning plans* [23] was installed and configured to facilitate the management, monitoring, and evaluation of learning outcomes. The implementation of the learning outcomes-oriented approach enables the teacher to assess learning outcomes semi-automatically and to consult the competency report for each learner. It also makes it possible to define an assessment scale and validation rules for learning outcomes, and to establish their relationships with learning objects during the configuration stage. Figure 8 shows a dashboard displaying learning outcomes and sub-learning outcomes in terms of skills acquired, in the process of being acquired or not acquired, together with information on the learners concerned. The level of acquisition is obtained through the automatic evaluation of learning objects containing the interaction elements required for automatic formative evaluations.

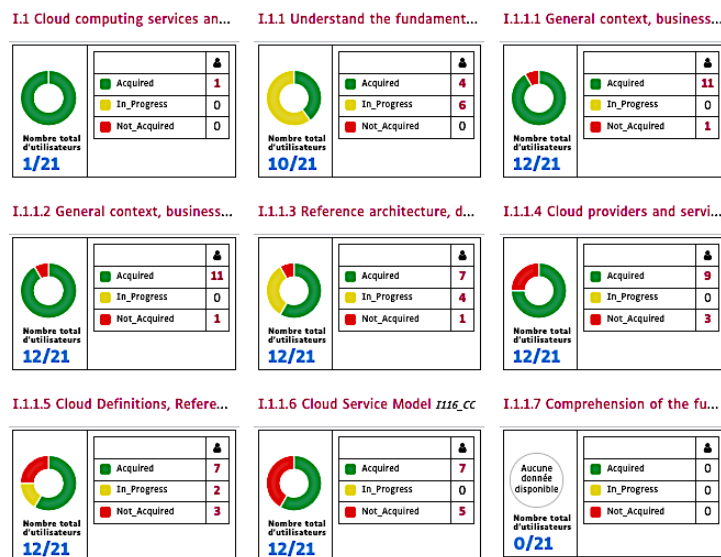


Figure 8: Dashboard of learner progress in terms of learning outcomes

VII.2 Monitoring and evaluating the progression, participation, and performance of learners

To monitor and evaluate the progression, participation, and performance of each learner, a second LA application has been developed based on statistical and mathematical techniques (see figure 9). The adoption of our instructional design methodology enables the construction of a dashboard that describes, diagnoses, and predicts the risk level of each learner for each course, based on the colored indicators green (zero risk), yellow (medium risk) or red (high risk). This enables the teacher to intervene early on students at risk, and the learner to have his or her individual information on progress, participation, and performance, as well as that of other learners, anonymously.

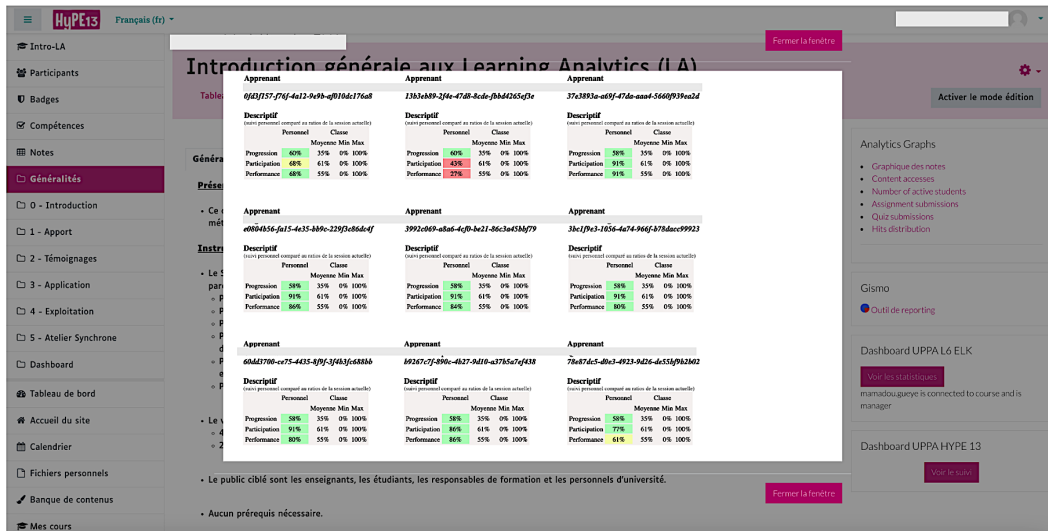


Figure 9: Dashboard for monitoring progression, participation, and performance of learners

VII.3 Monitoring and evaluation of the learning process, learning paths and use of learning content

For monitoring and evaluating the learning process and learning paths followed by learners, as well as assessing the use and quality of learning content, a third application of LA was carried out, based on Process Mining techniques with the Celonis platform [24]. By adopting our approach, the teacher can take better advantage of the contributions of LAs by exploring part or all the learning process and gaining general information on how it unfolds (see Figure 10). It also offers the possibility of seeing how often learning objects are consulted, the transition time between them, etc. (see figure 11).

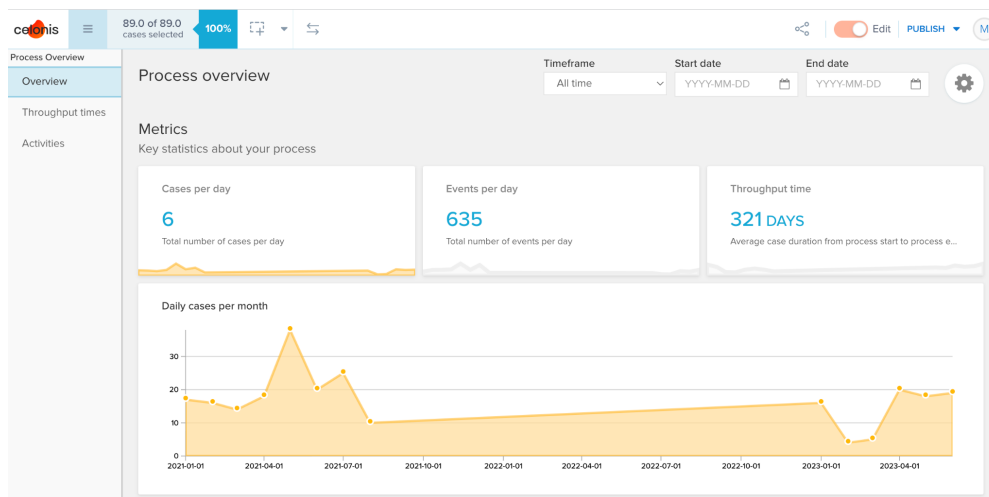


Figure 10: Learning process general information

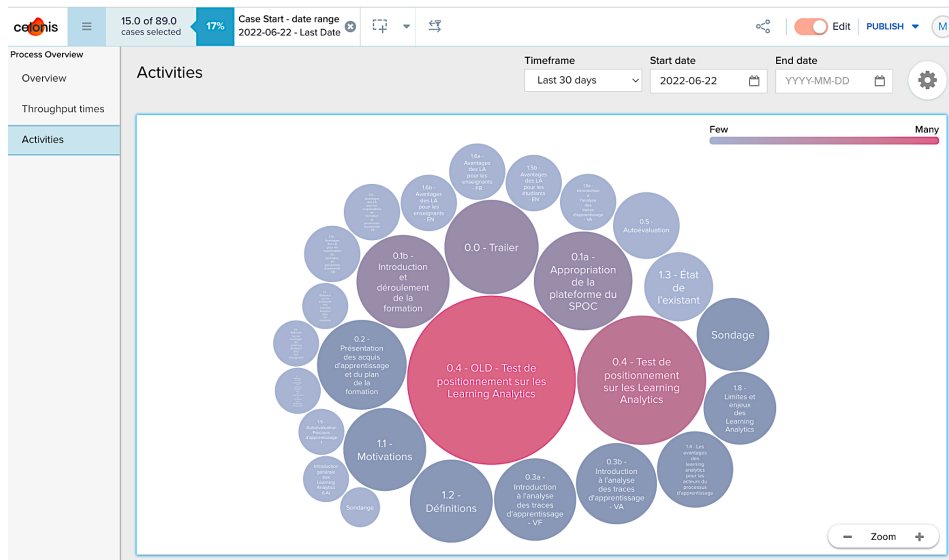


Figure 11: Frequency of use of learning resources

The teacher can also visualize the learning paths followed by all learners during the learning process, with an overview of each learner's path (see figure 12).

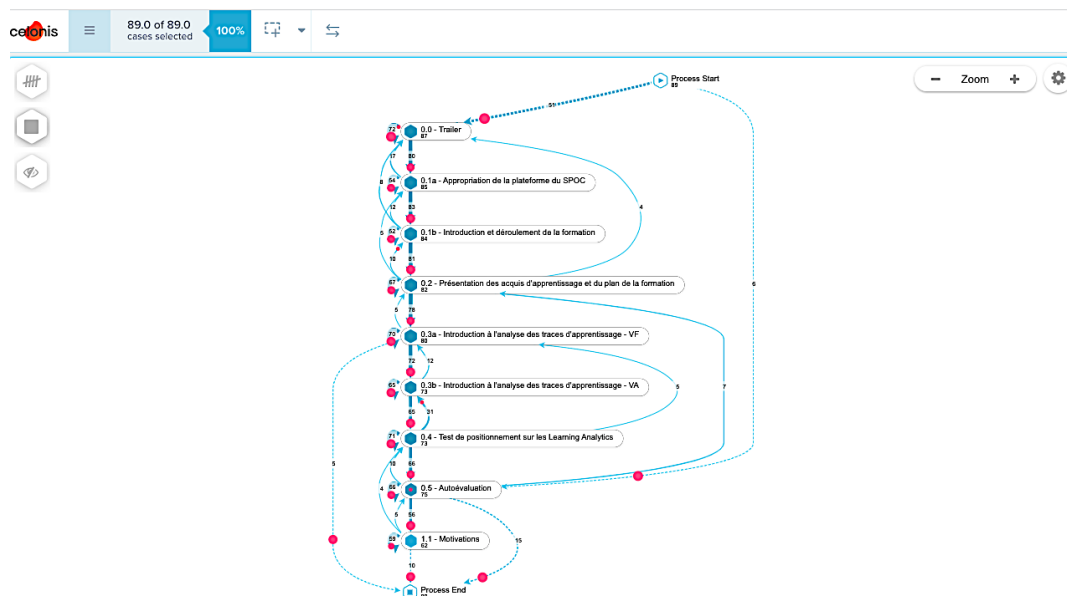


Figure 12: Visualization of learner learning paths

VIII. Evaluation et validation

To evaluate and validate our instructional design methodology, we produced a survey for SPOC participants. This survey contains seventeen questions (for the overall evaluation of the training), but we are interested in the ten questions relating to the evaluation of our approach (see Table 8).

Question	Description
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Q1	<i>Do the proposed resources meet your expectations?</i>
Q2	<i>Are the proposed activities relevant to the acquisition of new knowledge and skills?</i>
Q3	<i>Are the learning paths presented in a logical order?</i>
Q4	<i>Is the SPOC structure easy to understand and navigate?</i>
Q5	<i>Is the hybrid format chosen appropriate for achieving the goals of this training program?</i>
Q6	<i>Starting up the platform and providing access to the resources and activities offered on the platform are clearly explained and easy to carry out.</i>
Q7	<i>Is the training program of high quality?</i>
Q8	<i>In general, how satisfied are you with the SPOC?</i>
Q9	<i>The most positive aspects of the training are...</i>
Q10	<i>The training could be improved by ...</i>

Table 8: List of survey questions

After the data have been collected, we analyzed the results obtained from 60% of participants who have completed the full training course (see Table 9).

Question	Results
Q1	44.44% of participants answered <i>Yes</i> , 29.63% <i>Don't know</i> and 25.93% <i>No</i> . The results of this question show that the profile of participants did indeed correspond to teachers with some experience in the domain.
Q2	77.78% of participants answered <i>Yes</i> , 11.11% <i>Don't know</i> and 11.1% <i>No</i> .
Q3	44.44% of participants responded with <i>Strongly Agree</i> , 40.74% with <i>Agree</i> , 7.41% with <i>Neutral</i> , 7.41% with <i>Disagree</i> and 0% with <i>Strongly Disagree</i> .
Q4	33.33% of participants answered with <i>Strongly agree</i> , 51.85% with <i>Agree</i> , 11.11% with <i>Neutral</i> , 3.7% with <i>Disagree</i> and 0% with <i>Strongly disagree</i> .
Q5	48.15% of participants answered with <i>Strongly agree</i> , 40.74% with <i>Agree</i> , 11.11% with <i>Neutral</i> , 0% with <i>Disagree</i> and 0% with <i>Strongly disagree</i> .
Q6	37.04% of participants answered with <i>Strongly Agree</i> , 51.85% with <i>Agree</i> , 11.11% with <i>Neutral</i> , 0% with <i>Disagree</i> and 0% with <i>Strongly Disagree</i> .

Q7	37.04% of participants answered with <i>Strongly Agree</i> , 51.85% with <i>Agree</i> , 11.11% with <i>Neutral</i> , 0% with <i>Disagree</i> and 0% with <i>Strongly Disagree</i> .
Q8	29.63% of participants answered with <i>Very satisfied</i> , 55.56% with <i>Rather satisfied</i> , 7.41% with <i>Neutral</i> , 7.41% with <i>Rather dissatisfied</i> and 0% with <i>Very dissatisfied</i> .
Q9	We have focused on the most positive aspects of the training, highlighted by the respondents and which are related to our teaching design methodology. These aspects revolve around the asynchronous modality to adapt to the learning pace of everyone, the synchronous modality of the practical part, the clarity of the vision of the pedagogical approach, the pedagogical alignment for greater coherence, the provision of resources and personal time management, the progressive evolution, as well as the formats and diversity of the activities.
Q10	We are interested in the recommendations for improvement concerning the diversity of learning object types, the integration of a discussion forum to encourage exchanges during the asynchronous part, and the development of the practical dimension.

Table 9: Results of the survey

To validate our instructional design methodology, we analyzed the overall results of the evaluations. The answers to questions Q1 and Q2 show that the proposed learning objects are relevant to the acquisition of knowledge and skills. The results of questions Q3 and Q4 show that the definition of learning paths contributes favorably to a better structuring of pedagogical content, as well as easy navigation through content. The evaluations obtained for questions Q5 and Q6 show that the design is appropriate for the conception and development of hybrid and/or distance training, and the easy availability of content thanks to the integration of ICTE. The results of the evaluations relating to questions Q7 and Q8 show a quality evaluation rate equal to 88.89% and a satisfaction rate equal to 85.19% for this training course carried out using our approach. The results obtained from question Q9 show that the learning outcomes-oriented approach makes a positive contribution to the pedagogical coherence and alignment needed to achieve the pedagogical objectives associated with a training course. Based on the recommendations relating to question Q10, the diversity of learning object types, the possibility of remote and asynchronous practical work, and the integration of a synchronous forum will be considered as part of a continuous improvement approach to teaching and the methodology itself.

IX. Discussions

In this contribution, we propose a pedagogical design methodology for a better practice of Learning Analytics. This approach enables us to better guide the learner's progress in terms of knowledge and skills acquisition, based on a wide range of pedagogical resources and activities.

It also encourages the use of learning objects in relation to expected learning outcomes, to build learning paths that enable effective monitoring of learner progress, while facilitating the teacher's mission. We have proposed a harmonious integration of pedagogical and digital innovations based on the adoption of our instructional design approach in the transformation of courses. This increases the ability to obtain precise, measurable information on the learning objects used, the results on knowledge acquisition, as well as the educational activities carried out and their results on skills acquisition, to make it less complex to monitor the progress, participation and performance of all learners taking part in a learning path. What's more, this contribution makes it easier to monitor learners and optimally manage their learning process, thanks to the adaptation and personalization of learning paths. Our approach also makes it possible to evaluate the quality of the learning objects used in the context of open access education for a wide range of learner profiles, interests, and learning rhythms. The results obtained showed the interest that LA practice using an approach guided by an instructional design methodology facilitates the collection of relevant traces necessary for a better implementation of LA solutions. To validate our approach, testimonials were collected from the audience who had finalized the training during the second SPOC launch (SPOC 2), in June 2021, with around two hundred participants.

The learners saw the value of the solution, which enables them to check the progress of their skills acquisition, and to find out about their own levels of progression, participation, and performance, as well as those of others and the class. According to these learners, the descriptive and diagnostic elements provided in real time on their progress enabled them to position themselves in relation to the rest of the class (class minimum, average and maximum) and to understand the reasons for this situation. The prescription elements enabled them to receive information on their learning paths followed, so that they could personalize and adapt their learning, as well as having access to recommendations of optimal learning paths for better learning success.

Feedback from teachers showed that the solution enabled them to monitor in real time their learners' progress in terms of teaching-related knowledge and skills, as well as progression, participation, and performance, on a course-wide scale, using descriptive elements. Teachers found the descriptive and diagnostic elements useful, providing them with relevant information on how objects are used, the actions performed by learners, the time spent on content, the course of the learning process, as well as the path followed by each of their learners. According to these teachers, the predictive elements have enabled them to identify learners at risk of failure in their courses, so they can intervene at an early stage. They were also able to assess the quality of their teaching based on information derived from learners' interactions with pedagogical content. Regarding the elements of prescription through the recommendation of an optimal learning path, the teachers felt that this could help them in structuring certain pedagogical contents of their courses.

In addition to some of the teachers' testimonials, training managers appreciated the ability to have a global view across several courses in a training program, and to better understand learner profiles. They found the information provided by the system useful, enabling them to carry out a qualitative assessment of a training course, with a view to improving both content and format. During the implementation of our methodology, we did not integrate virtual learning environments used in the carrying out of learning activities or projects in asynchronous or

asynchronous mode. These environments enable learning objects to be developed in different formats, with the integration of tools such as a network simulator, an integrated development environment and an IoT project simulator to collect a large volume of learning traces relating to practical work and projects carried out by students. This development would enable all the dimensions of a learning path to be considered, and various data sources to be used for complete collection and analysis of learning traces.

In the case of the LA solutions implemented, the recommendation system does not provide an overview of the status of recommendations, to see whether they have been applied. In addition to the results obtained, it would be interesting to develop reinforcement recommendation models to automate the recommendation of learning content based on the learning experience and profile of each learner should also be integrated.

Implementation of the methodology is currently limited to the size of a Small Private Online Course (SPOC) with over 200 participants. However, larger-scale implementations of the methodology are planned as part of a project developed by an alliance of twelve universities supported by the European Union, of which our institution is a member, with the aim of developing a collaborative platform and methodological framework for innovation in teaching and learning. Another implementation is planned at our university, which has some 14,000 students, over 1,000 teachers and 120 courses. These future large-scale implementations will enable us, via more complex and challenging educational scenarios, to carry out a more complete validation of the global solution of this research work.

Conclusions et perspectives

Learning analytics cannot easily reflect the link between a learning resources and activities and the learning outcomes if this relationship is not explicitly expressed by the teacher, hence the interest in using an instructional design. Therefore, thinking about learning data and its analysis (Learning Analytics) in the digital ecosystem appeared to us as an obvious way to optimize the preparation and efficient analysis of learning data.

With our approach for instructional design, the collection is limited only to data relevant to the purpose of the LA practice for better consideration of certain ethical aspects` As a result, it would avoid spending too much time and energy in the preparation and analysis phases of the data for an efficient exploitation of the contributions of LA. This course design methodology also guides the collection and analysis of learning traces to better exploit the contributions of Learning Analytics and to help decision-making at least at the operational, management and strategic levels within educational organizations. The first results have shown that the adoption of our methodology, in addition to defining the objects, the learning outcomes and the learning paths, also allows specifying the sensors that need to be deployed to efficiently collect the traces and allow for an adequate analysis by LA technologies. This approach allows to explicitly create relationships between objects, learning outcomes and learning paths and thus to make Learning Analytics very effective for tracking learners in asynchronous courses.

However, at this stage of the implementation of our pedagogical design methodology, we have mainly focused on the theoretical dimension of learning that mainly promotes the acquisition of knowledge, as it occurs in a lecture. Indeed, most of the learning objects developed and evaluated were oriented towards replacing traditional courses according to flipped classroom

modalities. Problem-based, project-based, and challenge-based pedagogy would require another type of more advanced dynamic objects, probably shared between learners. This type of object could be built based on the development of virtual work environments, which would allow to support learners in the acquisition and application of skills, and at the same time to provide the necessary learning traces to ensure the corresponding follow-up and remediation plans. Moreover, in the implementation of our proposal, the LMS is the only source of learning traces from the learning environment.

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