Multi-scenario Modelling of Learning

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Abstract. Designing an educational scenario is a sensitive and challenging activity because it is the vector of learning. However, the designed scenario may not correspond to some learners' characteristics (pace of work, cognitive styles, emotional factors, prerequisite knowledge, …). To personalize the learning task and adapt it gradually to each learner, several scenarios are needed. Adaptation and personalization are difficult because it is necessary on the one hand to know in advance the profiles and on the other hand to produce the multiple scenarios corresponding to these profiles. Our model allows to design many scenarios without knowing the learner profiles beforehand. Furthermore, it offers each learner opportunities to choose a scenario and to change it during their learning process. The model ensures that all announced objectives have enough resources for acquiring knowledge and activities for evaluation.

Keywords: Adaptation · E-learning · Learning scenario · Instructional design Learning path

1 Introduction

This work is in the field of personalization and adaptation of technology enhanced learning to make the process of acquiring knowledge more effective. Many researches are carried out in this direction: they are interested in learner models [1], intelligent tutoring systems [2], analysis of learning traces [3] or adapting educational scenarios according to the learners' profiles [4], sometimes according to multiple sources [5].

The pedagogical scenario is the description of a learning sequence, its educational goals and the means to implement it to achieve these goals. The educational scenario is a key element in learning because it is the vector of learning [6]. In a context of lifelong or even initial training, it is extremely difficult to design a scenario for each learner. Some authors rely on learners' profiles to reduce the number of possibilities. To determine learners' profiles, learning data must be available and analysed, which is time-consuming. After determining the profiles, it can happen that we have found several profiles, making the number of scenarios to conceive always enough. Moreover, during learning, the knowledge acquired by a learner and interactions with the learning environment can change their profile. For example, a learner without much computer experience at the beginning of the learning session will have a poor

C. M. F. Kebe et al. (Eds.): InterSol 2018, LNICST 249, pp. 199–211, 2018.
https://doi.org/10.1007/978-3-319-98878-8_19

performance that will improve during their learning as they acquire new computer skills. This evolution of the profile may render the initially proposed scenario inappropriate. Moreover, nothing can ensure that this new profile will match one of the identified profiles. Therefore, the teacher would need to be regularly designing new personalized scenarios as new profiles are identified, which is difficult to do.

Thus, there is a problem of designing several scenarios to adapt to the particularities of learners. We choose to break down an educational scenario into a learning scenario (related to learner) and a coaching scenario (for the teacher) that should be structured, coherent and combined to drive learning [7]. In this paper, we are interested in the learning scenario part, which is the description of the proposed learning activities, their articulation in the learning sequence as well as the expected results of learners [8]. Although this scenario is intended for the learners, its design is to be done by the teachers. Our research focuses on providing teachers with conceptual and technological tools to design a course with several learning scenarios without knowing in advance the profiles of learners.

The remainder of this paper is organized as follows. In Sect. 2, we describe the state of the art of scenario models and more specifically learning scenarios. In Sect. 3, we present our multi-scenario model of a course. In Sect. 4 we describe the implementation of our system into the LMS (Learning Management System) Moodle. In Sect. 5, we report the results of an acceptability questionnaire filled by teachers to assess the quality of their educational productions, their predispositions to personalize learners' follow-up and their resistance to change their teaching method. Finally, in Sect. 6 we present the results of an experiment involving teachers using our system during a multi-scenario course design workshop.

2 State of Art

The design of an educational scenario integrating ICT (Information and Communication Technologies) is a fundamental activity to guarantee the quality of learning by considering the training system. Based on the EML (Educational Modelling Language), most models of learning scenarios are designed as a succession of activities or tasks that the learner needs to perform to reach their learning goal. Some models divide activities based on educational goals [9]. Others propose a division based on teachers' intentions [10] take into account activities to be done by learners, teachers' intentions and interactions [11].

To carry out the division based on teachers' intentions, a set of questions must be asked to make relevant pedagogical choices. Brassard and Daele have identified 17 dimensions of questions organized into 4 categories [12]. To consider the learners' specificities, they suggest a dimension which proposes alternative or variable paths linking the activities in the scenario. The difficulty of this implementation relies on the "a priori knowledge" of learners' characteristics (cognitive styles, emotional factors, prerequisite knowledge…). Moreover, it would be tedious to implement a pedagogical scenario with these 17 dimensions, to produce as many scenarios as possible (learners' categories).

In order to produce new scenarios, Riad et al. [13] propose the reuse and the adaptation of the existing scenario to create new ones. Nevertheless, the weakness of their approach is the impossibility to modify the scenario structure. Their adaptation consists only in modifying included resources. Using the principle of design patterns, Marne and Labat [14] propose to see activities with several states of input and output. The connections among states depend on the prerequisites between the activities and objectives achieved by the learner. The advantage of this approach relies on its flexibility in the sequence of activities, but it does not take into account a learners' profiles and is not intended to define several scenarios for a same session.

The Competence-based Knowledge Space Theory (CbKST), an extension of the Knowledge Space Theory (KST) [15] proposes a knowledge structure model based on competences for the personalization of learning [16]. The model considers precedence's relationships between competences to establish the notion of knowledge state (set of skills acquired in a field). From the different states, the CbKST allows to establish several learning paths to achieve the same goal. Thus, the CbKST provides a framework for designing multiple learning scenarios in a transparent way for teacher.

3 Multi-scenario Model

3.1 Main Objectives

Our model is inspired by the CbKST given its many successes in various fields such as medicine [17], metacognition [18], education [19] and more specifically Serious Games [20]. However, models based on CbKST have three main weaknesses:

- **Lack of support for activities with multiple competences**
  In studied models, the activities allow to work and acquire only one competence at a time. In our context, activities with multiple competences (such as studies case [21]) provide to learners the possibility to use diverse or even low-level competences to solve higher-level problems. It also allows the learner to acquire new competences from those acquired. These are complex activities highly recommended in a training.
- **No temporal constraints**
  Although the learning process has for general objective acquiring and evaluating acquired knowledge, this must be done within a given time defined by the conditions of the training. But the models of the CbKST do not take this constraint into account.
- **No levels or thresholds of learning satisfaction**
  In models based on the CbKST, the acquisition of the competence is boolean (true or false). However, in a system of initial or continuous training, the acquisition of a competence is subject to a minimum threshold of satisfaction that the learner must reach. Moreover, a competency not acquired can be obtained by compensation as advised by the system (Bachelor - Master - Doctorate) in higher education.

The goal of our model is to provide for the teacher a tool to design several learning scenarios taking into account these different learning constraints. Our model is based on a set of initial concepts that we describe and justify below, and which have been validated by the teaching staff as we will show in Sect. 6.

3.2 The Initial Concepts

Inspired of the teachers' practice, our concepts are based on learning objects. Relationships among concepts are represented by the following class diagram (Fig. 1):

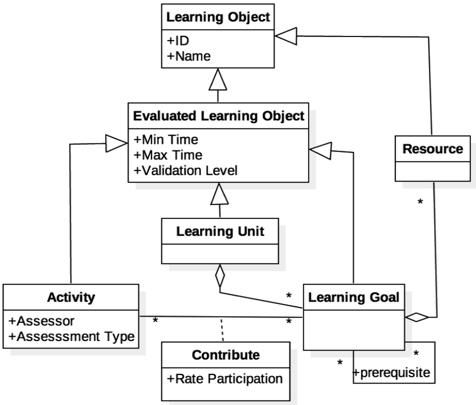


Fig. 1. Class diagram of learning objects

3.2.1 Learning Decomposition in Unit

To be close to teaching practices, a learning or training module is divided into learning units with precedence relationships. These units correspond to the notions of chapter, part, title, etc. Each unit contains a set of learning goals.

3.2.2 Learner-Centered Pedagogy and Structuration by Learning Goals

Most of current pedagogical approaches structure content in parts, chapters, titles, etc. However, our model structures content in learning goals. Each goal has a set of learning resources (R_j^i) for knowledge acquisition and a set of learning activities (A_j^i) for validating acquired knowledge. The acquisition and validation of the knowledge associated with each objective has a duration (T_i) and is conditioned by a satisfaction threshold (S_i). An objective O_i is defined as follows:

$$\mathbf{O_i} = \left\{T_i, S_i, \left\{R_1^i, R_2^i, \ldots, R_{Pi}^i\right\}, \left\{A_1^i, A_2^i, \ldots, A_{Ni}^i\right\}\right\} \text{ with } (P_i, N_i) \in \mathrm{IN}^2 - \{(0,0)\}.$$

P_i is number of learning resources and N_i is number of learning activities.

The goals have prerequisite relationships among them.

3.2.3 Indexing Activities by Learning Goals

The model defines for each activity, the necessary goals for its realization. Likewise, the model ensures that each goal has enough activities to assess and validate acquired knowledge. For this, the model has a matrix ($\mathbf{A_j^i}$) where activities are in line and goals in column. The matrix contains participation rates of each activity for assessing and validating each goal. Thus, each activity $\mathbf{A_j^i}$ participates in the validation of the objective $\mathbf{O_i}$ with a rate $\mathbf{P_j^i}$ where $\sum_{j=1}^{Ni} P_j^i \geq \mathbf{100\%}$. The model can therefore handle activities with multiple goals.

3.2.4 Acquisition and Validation of Knowledge

Although the acquisition of knowledge is done by using the learning resources, our model does not take into account the fact that learners really use resources. This choice is justified by the fact that, on the one hand, we do not have means to ensure that the resource is actually being used; on the other hand, a learner may have already acquired the knowledge contained in the resource in a previous training. To ensure that knowledge is acquired, the model validates it by learning activities. An activity $\mathbf{A_j^i}$ is validated if the obtained score $\mathbf{V_j^i}$ is greater than or equal to the threshold $\mathbf{S_j^i}$ of validation of the activity.

An objective $\mathbf{O_i}$ is validated if there is a time $\mathbf{t}$ such as $\mathbf{t} < \mathbf{T_i} \sum_{j=1}^{Ni} P_j^i V_j^i \geq \mathbf{S_i}$.

3.3 Determination of Learning Paths

To determine learning paths, first the knowledge structure containing knowledge states must be generated.

```
    Algorithm of generation of the knowledge structure
Input: G Graph of prerequisites among learning goals
Output: K Knowledge structure (set of knowledge states)
Variables: A and B are learning goals; Q, E are
knowledge state (set of learning goals)
K = {∅} ∪ {Q}
For any unmarked state E of K
  For each goal A ∈ E do
   If there is no goal B in G such that A → B then
      K = K ∪ {E-{A}}
  End For
  Mark(E)
End For
```

From the knowledge structure, the learning paths are determined from the notions of internal and external fringes defined in the KST [15]. The internal (respectively external) fringe of a knowledge state K is the set of goals P such as deleting them (respectively adding them) to K, we obtain another state of knowledge which is immediately lower (respectively higher).

3.4 Impact of Activities with Multiple Goals in Learning Paths

According to KST, a validated knowledge implies its acquisition. Regardless of their current learning state, if the learner decides to do an activity with multiple goals and validates it, then they acquire the goals targeted by this activity. This validation is conditioned by the fact that the score obtained on the activity allows for the validation threshold of each goal to be exceeded.

Example: Considering learning goals a, b, c, d, e, f, and g with their prerequisite relationships, as shown on the graph in Fig. 2. By applying the CbKST approach, we can generate the learning paths (Fig. 3). Suppose that an activity targets goals c and d. The state of knowledge {c, d} is not admissible (possible) because:

- the acquisition (validation) of **c** is conditioned by acquisition of **b**
- the acquisition (validation) of **d** is conditioned by acquisition of **a**.

So, the knowledge state associated with the acquisition of c and d is the state {a, b, c, d}. It is accessible from any state which is inferior to it. It is possible by the validation of an activity with multiple goals (green lines in Fig. 4).

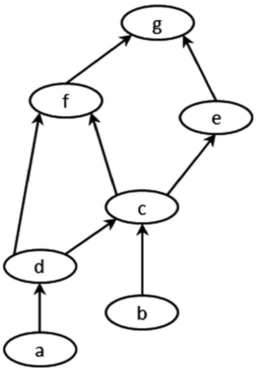


Fig. 2. Graph of prerequisites among goals

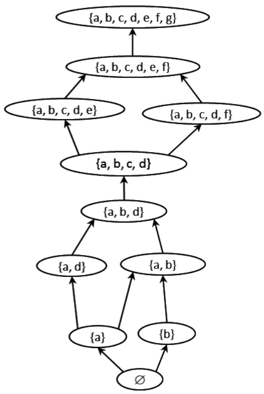


Fig. 3. Graph of learning paths

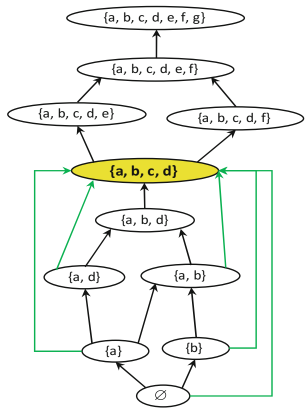


Fig. 4. Graph of augmented learning paths (Color figure online)

The activity with multiple goals increases new learning paths, leading us to the notion of augmented learning path, and the associated notions of augmented knowledge state and augmented link, defined as follows:

- **Augmented knowledge state:** a knowledge state is augmented (yellow state in Fig. 4) if it can be obtained from the validation of an activity with multiple goals. Because it's augmented, from any state that is inferior to it, the learner can access it without going through the intermediate states.
- **Augmented link:** A link from state E1 to state E2 is augmented (green link in Fig. 4) if E2 is an augmented state and E1 is not an immediately lower state of E2.
- **Augmented learning path:** A learning path is augmented if there is at least one augmented link in its list of links.

Augmented learning paths offer challengers or talented learners the opportunity to progress quickly in the acquisition of competences. An acceptable competence level as defined by the teacher can be reached the same way during this quick progress.

4 Implementation: The EGbKST Plugin

Although the previous model is independent of any learning platform, we decided to implement it as plugin for the MOODLE[1] platform (Modular Object-Oriented Dynamic Learning Environment), used in our university. The plugin is named EGbKST (Educational Goals Based Knowledge Space Theory). To show the difference between our new system and the current system, we will first present the system based on the current pedagogical model.

Table 1. Structuring learning in our current pedagogical model

General information	This section situates the course in the training and contains information about the authors
General goals	The different general goals of the course
Work instructions	Work instructions before, during and after learning
Preliminary activities	This section contains the prerequisites of course, an entrance test, keywords, course summary, bibliography, webography and a tool to choose a team for collaborative work
Communication	The different communication tools to use during the learning
Sequence 1	The course is divided in sequence (part, chapter, title, section,…). Each contains a title, a duration, a set of specific goals, a set of resources and a set of exercises
…	
Sequence N	

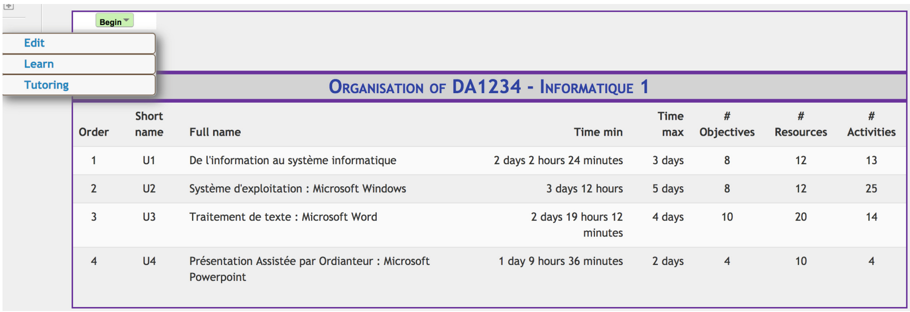
In our current pedagogical model (represented in MOODLE system), learning and evaluation are organized in sequences. The model does not ensure that the defined goals have resources for knowledge acquisition and exercises for evaluation. The evaluation made at the end of the sequence does not allow to anticipate learners' failure because the sequence contains many goals and its duration is of approximatively 2 weeks: any failure is therefore detected only when it is too late.

[1] https://moodle.org/.

In our system, we chose to keep the first 3 sections (from Table 1) to allow learners to have access to general information, general objectives and work instructions before starting learning. We added a fourth section including the EGbKST plugin used to design a course according to our model. The plugin integrates 3 roles: teacher (course design), student (learning) and tutor (tutoring). In this paper, since we are interested in course design, we will only present the views associated to the teacher role. To design their course, the teacher has many interfaces and proceeds as follows:

1. Adding metadata such as general goals, prerequisites, bibliography, keywords, …
2. Adding learning units. For example, "The exercise of political power"
3. Adding learning goals. For example, "Distinguish theories of sovereignty"
4. Adding precedence links among goals. For example, "Identify limits of powers separation" is a prerequisite for "Describe relativity of separation"
5. Adding learning resources by goal. For example, a document, web link, video, etc.
6. Adding learning activities with specifying participation rate of associated goals
7. Generation of knowledge structure and learning paths.

To facilitate course editing, we designed an Excel workbook[2] that allows teachers to enter all course data. The workbook contains the course information cited above. Its content is exported to CSV (Comma-Separated Values) files and imported into the system. The teacher must generate knowledge structure and learning paths (Fig. 5).



Order	Short name	Full name	Time min	Time max	# Objectives	# Resources	# Activities
1	U1	De l'information au système informatique	2 days 2 hours 24 minutes	3 days	8	12	13
2	U2	Système d'exploitation : Microsoft Windows	3 days 12 hours	5 days	8	12	25
3	U3	Traitement de texte : Microsoft Word	2 days 19 hours 12 minutes	4 days	10	20	14
4	U4	Présentation Assistée par Ordianteur : Microsoft Powerpoint	1 day 9 hours 36 minutes	2 days	4	10	4

Fig. 5. Interface after editing (importing) the educational structure of course

Our system allows the teacher to focus on only one goal at the time during content producing. The organisation of contents is done by system. It is easy to reuse this content in another course. The system ensures that all goals have content and are evaluated. The distribution of learning time by goal allows the teacher to better estimate the workload of learners.

[2] https://drive.google.com/file/d/1jVAIQecZQgiKsaiJ6yUOZymBG9qSQkHo.

5 Assessing the Acceptability of the Model by Teachers

Before proposing the model to the teachers for designing their courses, we wanted to assess its acceptability and teachers' willingness to use it. For this, a survey[3] was submitted to university teachers on the following aspects:

- **Educational productions:** self-assessment of the quality of their courses in terms of (1) structuring, (2) content and evaluation according to the goals of course and (3) organization of the course notions.
- **Interest in customizing the students' learning progress**
- **Resistance to change in teaching method**

The survey has been sent to all teachers and tutors[4] of our university. Out of 125 persons contacted, we have received $N = 64$ answers[5]. The participants were from 16 departments of university, their age varying between under 25 to over 60 years ($M = 39.25$, $SD = 7.99$) and their teaching seniority varying from less than 2 years to more than 30 years ($M = 10.26$, $SD = 6.64$).

Participants reported that their pedagogical productions are organized mostly in chapters (78.70%) and often in part (23.40%), title (21.30%) and other (4.20%). Nearly 25% of participants believed that certain learning goals have no learning resources clearly identifiable by learners to acquire knowledge. It is also true for exercises used to evaluate acquired knowledge. This confirms the interest to justify association to each goal, resources and exercises to better structure the teaching and facilitate learning.

Regardless of their seniority, 83% of teachers believed that they did not have the best educational scenario. As a result, we believe that the best scenario will depend on the learners since they are the main beneficiary of the teaching.

To follow learners in their chosen scenario, nearly 90% of teachers declared they were ready to cater to learners late in their learning and 55% were willing to follow learners progressing faster in their learning. 63% of them declared being willing to spend some time to help learners outside of the scheduled sessions. Those results confirm the validity of our approach to give opportunity to all learners to finish their learning considering their cognitive characteristics.

Surprisingly, as we expected many teachers to be reluctant to changing their teaching method, 80% of teachers thought it was better to organize the teaching or learning by educational goal, instead of by chapters or parts as usual. More than 90% of them estimated that exercises should be classified by goal to facilitate their resolution. Nearly 80% found that assessment by goal would be better than assessment by period (generally at the end of a chapter, part or even semester).

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[3] https://goo.gl/forms/ne1Uua4UeYPW3EeO2.

[4] Person responsible of the educational follow-up in the online training platform.

[5] Consulted at 11-24-2017.

6 Assessing the Usability of the System

To evaluate the usability of EGbKST and its underlying model, we organized a workshop to use our system, attended by 16 teachers from 3 higher education institutions and 8 specialties (Economics, Geography, Management, Computer Science, Applied Foreign Languages, Modern Letters, Management and Law Sciences). We had thus the opportunity to test our model in different domains and therefore to validate the genericity of our approach.

6.1 Methodology

The experiment was organized into 4 parts. In part 1, we presented to the participants the previous survey to get their opinion before the experiment. In the part 2, we asked participants to interpret the result of survey and to criticize the current model according to them. We then exposed the need to improve the pedagogical model. The improvement focused on the possibility of having several scenarios in a course to consider learners' specificities. The concepts of our model were presented to allow them to understand their logic and usefulness. In part 3, participants had to redesign their own courses according to model. This was done through the Excel workbook designed for this purpose. At each stage, we explained to the participants the expected results. Participants' productions were presented to all assistance for verification and improvement. Part 4 of the experiment dealt with another survey[6] (a posteriori) to collect the appreciation of model and difficulties of implementation.

The experiment was focused more on the pedagogical part (production of course) than the technological part (implementing course on Moodle platform).

6.2 Results

Pedagogically, our model allowed to detect in educational productions some knowledge taught before their prerequisites. These imperfections have been corrected using precedence relationships established between goals.

The graph of prerequisite among goals showed that many courses have several educational goals without or with only few prerequisites. For example, Table 2 shows among the 16 courses currently in production, the teaching unit "Constitutional Law 2" taught in the first year of the Bachelor's degree in Business Law. The teaching is structured in 2 lessons in which the first has 7 goals and the second 11. Figure 6 illustrates the low number of prerequisites between goals found for that course.

In many cases, the teachers realized that they forced a pedagogical scenario although several other scenarios were just as valid. In the example on Fig. 6, we realize that on the 18 goals, 9 have no prerequisite. A learner can begin learning by the end of the course (according the teacher's scenario) without risk.

[6] https://goo.gl/forms/eSaZjajB2x744RdQ2.

Table 2. The learning goals of “Constitutional Law 2” course

Lesson 1	Constitutional organization of democratic power
Goal 101:	Distinguish theories of sovereignty
Goal 102:	Describe institutional consequences of democratic theories of sovereignty
Goal 103:	Describe perverse effects of national sovereignty
Goal 104:	Interpret utopia of popular sovereignty
Goal 105:	Explain the amalgam of democratic theories of sovereignty
Goal 106:	Recognize the main voting methods
Goal 107:	Explain the political implications of the main voting methods
Lesson 2	The exercise of political power
Goal 201:	Distinguish theories of the powers separation
Goal 202:	Explain objectives of the powers separation
Goal 203:	Determine the fundamental principles of powers separation
Goal 204:	Identify limits of powers separation
Goal 205:	Identify different political regimes
Goal 206:	Describe particularity of parliamentary regime
Goal 207:	Summarize origin of the parliamentary system
Goal 208:	Discuss characteristics of the parliamentary system
Goal 209:	Describe relativity of separation
Goal 210:	Name characteristics of presidential regime
Goal 211:	Interpreting complexity of political regimes application in Africa

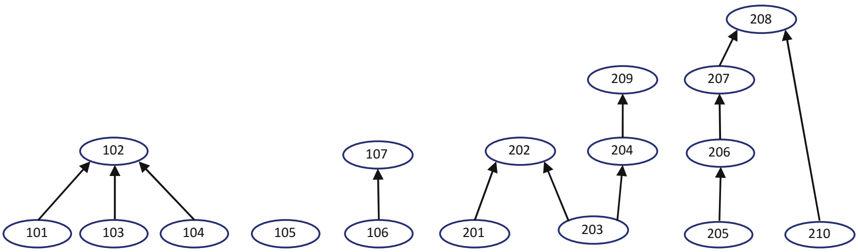

Fig. 6. Graph of prerequisite goals of “Constitutional Law 2” teaching unit

In the final survey, 100% of the teachers declared appreciating our approach to better structure the lessons and organize evaluations, but 42.8% declared using our model was difficult and would have needed more time to experiment. The main difficulty was to index educational resources and activities by educational goals.

7 Conclusion

Designing a learning scenario (by teacher) is a time-consuming activity, making it difficult for teachers to build several scenarios. However, learners with different characteristics may have difficulties to follow the unique scenario defined by teacher.

We have therefore proposed a model to design multi-scenario in courses based on prerequisite relationships between educational goals. Our model allows to design easily several scenarios without knowing in advance the specific characteristics of each learner.

From an experiment made with our system, the teachers have both detected contradictions contained in their productions and realized that several goals of their courses were not related to others. These findings have led some teachers to review their course design and to generate new scenarios. Most teachers realized that learning assessment does not cover all goals. The proposed activities cover even very few goals and generally focus on case studies. But to do this kind of activity, it is necessary to make sure that learners have really acquired the basic competences. This is done through particular activities defined around one skill or learning goal. Our experience was inconsistent in the choice of participants because their competence in e-learning was very different.

In future works, we intend to integrate into the model and the tool, an analysis of the learning scenarios chosen by learners that we will present to the teachers. This analysis will probably allow them to detect hidden dependencies. On the other hand, the quality and the achieving time of learner's results will make possible to better set learning durations for goals and to have a more accurate feedback on the effective implementation of their learning scenarios. To allow teacher to follow the learners in their different scenarios, we will design the coaching scenario.

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