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PROPOSING AND EVALUATING A MODEL OF CO-CONSTRUCTION OF THE LEARNING SCENARIO BY THE LEARNER

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ABSTRACT

To improve the learning process, the evolution of learner's characteristics (cognitive, affective, prior knowledge, workflow, organization, ...) must be taken into account during the personalization or adaptation. This requires generating several scenarios (a description of activities, their order and links in the learning sequence as well as the expected outcome for the learner) adapted to the identified profiles. We propose a model which aims at improving learners' learning processes by giving them control over two key aspects: (1) the steps of the learning scenario to be followed: after each learning goal is completed, the learner chooses the next one among the possible ones (in terms of their current knowledge) while respecting pedagogical constraints (time and quality of the solutions produced according to satisfaction thresholds); (2) the assessment mode: the learner chooses a mode corresponding to their own goals in terms of mastery, while respecting the minimum thresholds set by the teacher. We assess our approach with learners in terms of (a) adequacy of the model with learners' expectations, (b) usability of the system and (c) learning experience satisfaction, through self-report questionnaires and an analysis of the data collected over 11 learners who used an implementation of our system on the LMS (Learning Management System) in the context of a real course on Economy. The results reveal an a priori acceptance of our model, a diversity of the scenarios constructed, and the use of 2 (out of 3) assessment modes to progress. We use these results to analyze current limits of the system and propose redesign ideas to minimize them.

KEYWORDS

Learner-directed Learning, Learning Challenge, Personalized Learning Scenario, Personalized Learning Goals, Co-construction of Learning Scenario, Learning Path

1. INTRODUCTION

The teacher creates a knowledge-based course with well-defined learning goals. The course is then organized in a scenario which guides teaching and learning. This standard scenario, as envisioned by the teacher, can be inappropriate or at least suboptimal for some learners, because the learning also depends on their personal characteristics (*e.g.* pace of work, cognitive styles, emotional factors, prior knowledge). To improve the learning process, it is therefore ideal for each learner to have their own personalized scenario. Moreover, while learning, some characteristics of the learner may change (*e.g.* more motivation to learn about a topic than another, less time because of personal issues), making the scenario, as defined initially, less and less appropriate. It would be difficult for the teacher, particularly in an online context, to detect the change in the learners' characteristics to propose a new adapted scenario. However, this detection is achievable by computer-based methods based on the exploitation of learning traces, learner modeling (Greer and McCalla, 2013) and intelligent tutoring systems (Ma et al., 2014). However, these methods usually require an important quantity of traces (hard for courses with few students enrolled) and when new profiles are detected the system may need reengineering or a refinement of some parameters. Thus, there can be issues relative to the real-time detection of changes in learner profiles to assign them an appropriate scenario. More fundamentally, various works on metacognition and self-regulation show that involving the learner, for instance by making them choose their learning goals, can lead to deeper learning and increased motivation (Harley et al., 2018), compared to a linear more passive way predefined by the teacher. This approach forces the learners to re-evaluate their decision if they realize they have chosen an activity for which they do not master yet all the required skills.

Following these observations, this paper focuses on the co-construction of the learning scenario by the learners, as they learn, to make the learning process or acquisition of knowledge more efficient. We use the term “co-construction” because although the next learning goal depends on the learner, the range of their choice is constrained by the teacher, to prevent them from making illogical choices (*e.g.* trying to acquire a competence before its prerequisite). In this context, our research questions are: (RQ1) Can we set up a model allowing each learner to co-construct his or her scenario during the learning process? (RQ2) Is such a model understandable and acceptable to learners? (RQ3) How do learners use the possibilities of co-construction made available to them? Our contribution is to provide learners with conceptual and technological tools to build their learning scenario in a learning context imposed by the teacher and supported by technology.

The remainder of this paper is organized as follows. In section 2, we present a brief overview of related works on personalization and adaptation of learning. Section 3 presents our model of co-construction of the learning scenario. Section 4 presents our implementation of the model in the LMS. Section 5 presents results of an evaluation of our approach in terms of acceptability of the model by learners, but also an evaluation of the system usability through an analysis of data collected in a preliminary experiment conducted in real situation with a class of students. We conclude on opportunities for some system redesign ideas.

2. RELATED WORK

The description of a learning scenario can be formalized with the Educational Modeling Language (EML) (Koper and Manderveld, 2004) which offers the modeling of reusable, interoperable, rich and customizable learning units. Through personalization and reuse, it is possible to design several scenarios, but the EML language does not provide ways to switch from one scenario to another during the learning. This is because the scenario design is generally based on the intentions of teachers (Emin et al., 2010) (teacher-centered pedagogy) and on pedagogical goals (Dalziel, 2008) (content-centered pedagogy). Some works have tried to be closer to a learner-centered pedagogy, for instance by taking into account teachers' intentions, activities to do by learners and learner interactions (Mariais et al., 2010).

To design a pedagogical scenario, (Esnault and Daele, 2003) defined 17 dimensions of question, taking into account learners’ individual differences. However, to take this personalization into account, the scenario designer must know the learners' profiles in advance. Even if new scenarios can be designed by reuse and adaptation of existing ones (Riad et al., 2012), profiles can evolve during the learning process and no personalized path corresponds to the new profile. (Marne and Labat, 2014) proposed a scenario based on activities with several input and output states. The links between activities based on prerequisite relationships among them makes it possible to have several learning paths. However, their model, defined in a context of serious games, does not give the learner the possibility to choose the scenario to follow.

The Competence-based Knowledge Space Theory (CbKST) offers a model for structuring competences-based learning for personalization (Heller et al., 2006). From the relationship of prerequisite among competences, the model constructs several recommended learning paths (Kopeinik et al., 2012). Each path is composed of knowledge states (set of competences acquired in a particular field). From a knowledge state, the learner progresses in their learning by choosing a competence to acquire that will bring them into a new higher knowledge state. The learning is complete when the learner is in the terminal knowledge state (state with all acquired competences). Although the CbKST offers several learning paths, it does not consider learning constraints (temporal and qualitative related to satisfaction threshold of activities) in choices of paths, nor multi-goal activities (*e.g.* case studies), nor the conditions to change paths (*e.g.* a change can take place after a certain number of failures or the incapability to reach a fixed goal or a temporal constraint non-respected).

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3. CO-CONSTRUCTION MODEL OF SCENARIO DURING LEARNING

3.1 Core Concepts of the Model

Knowledge acquisition is rarely linear: there are many ways to do it, depending on the learning goal. But to build a scenario, the course design model must allow it. Our model relies on five concepts (*cf.* Figure 1):

1. **Decomposition of knowledge by learning goal to be achieved.** Time constraints are associated with each goal. Satisfaction thresholds are added to constrain learners' efforts.
2. **Encapsulation of knowledge in learning resources for learning goals.** This encapsulation guarantees modularity in a course since a resource is reusable in another course without modification.
3. **Assessment of acquired knowledge.** We define activities to assess the learning. To prevent assessment from depending on only one activity, we define for each activity a percentage of participation in knowledge validation. An activity can also contribute to the validation of several knowledge.
4. **Prerequisites between knowledge.** There can be many ways to learn a course, but there are nevertheless order constraints, taken into account in our model by a prerequisites graph between the goals.
5. **Grouping learning goals into learning units.** To be close to the teachers' practice, the goals are grouped into learning units (generally parts, chapters, titles, ...).

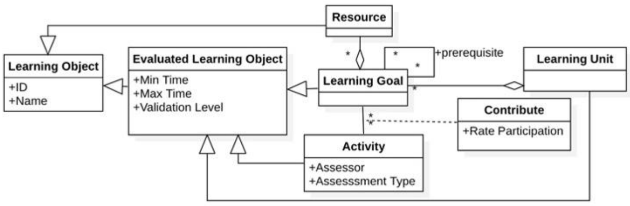

Figure 1. Class diagram of learning objects for course design

Our model constructs several learning scenarios by articulating the learning objects. In a previous work, we have also assessed our model acceptability (https://goo.gl/forms/ne1Uua4UeYPW3EeO2) from the teacher's point of view (Mbatchou et al., 2018), showing their willingness to use it. An experiment with 16 teachers from 8 specialties also allowed us to (1) detect and correct the inconsistencies in their educational productions; (2) find that certain goals of their course are not related to others; (3) find that there is little prerequisite relationship between goals; (4) to note the multiplicity of scenarios in their course.

3.2 Scenario Building

The model is meant to provide learners with an environment allowing them to learn the way they want while respecting the rules and constraints of learning. We assume that we do not have a priori learner profiles, as learners' profiles are dynamic and we do not want to regularly ask learners to self-report their motivation, time, etc. Learners need to build their scenario as they learn. The model is based on knowledge states to enable each learner to situate themselves in their learning and to progress. A knowledge state is a state that describes acquired and validated knowledge by a learner; it is composed by achieved learning goals. The knowledge states are produced and associated according to the Knowledge Spaces Theory to obtain different learning paths. The learning process is to guide the learner from initial state to final state. The learning constraints defined by the teacher when designing learning objects is an implicit guidance contributing to co-construction. Learning is supervised by a human tutor as a learning facilitator (role not detailed in this paper).

During the learning process, the system determines the learner's knowledge state and offers them a set of goals to achieve. Then for the chosen goal, the system proposes a set of resources and activities that will allow them to reach it. After an assessment that the knowledge is acquired, the system determines their new knowledge state. If they are unable to perform a given activity (resp. progress in a chosen scenario), the learner can abandon it and choose another activity (resp. scenario) offered by the system in the same scenario (resp. according to the learning goals).

The model integrates knowledge assessment modes to progress in learning. The choice of the mode depends on the challenge that the learner sets for themselves at any moment. Since the learner is situated in learning by their knowledge state, suppose a state with P goals $\{G_1, G_2, \ldots, G_P\}$. Each G_i has a set of learning activities $\{A^i_1, A^i_2, \ldots, A^i_{Ni}\}$ for validating the acquired knowledge. Each activity A^i_j has a percentage of participation P^i_j to achieve the goal G_i. When a learner chooses to perform the activity A^i_j we keep the obtained value V^i_j to compute the score obtained for this goal. The validation of each goal (G_i) is constrained by a threshold (S_i). To validate his state with P goals, the learner has the following modes:

Assessment mode by flexible compensation. The state is validated if $\sum_{i=1}^{P}\sum_{j=1}^{N_i} P^i_j V^i_j \geq \sum_{i=1}^{P} S_i$. So, learner can progress with few efforts made on certain goals because he can obtain them by compensation.

Assessment mode by restrictive compensation. With the previous mode, a learner can validate a state even with one goal with a very low level of satisfaction. To avoid this case, in compensation mode, the learner must make minimum efforts for each goal. The state is validated if $\prod_{i=1}^{P}\sum_{j=1}^{Ni} P^i_j V^i_j \geq \prod_{i=1}^{P} S_i$.

Strict assessment mode. This mode allows challengers learners to master all goals of a state before progressing. The state is validated if $\forall\, \mathbf{i},\ 1 \leq \mathbf{i} \leq \mathbf{P},\ \sum_{j=1}^{Ni} P^i_j V^i_j \geq S_i$. The quality of the built scenario is better if the strict mode is used throughout the learning.

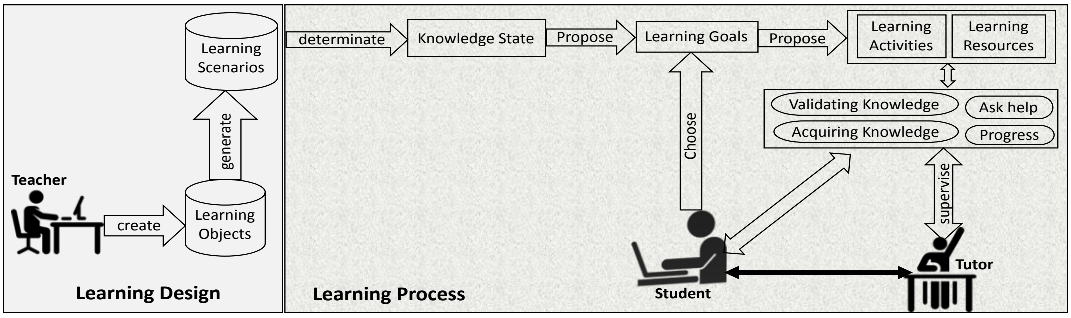

Figure 2. Learning process

4. SYSTEM OVERVIEW

We chose to implement our model as a plugin in MOODLE (Modular-Object Oriented Dynamic Learning Environment), which is the LMS used in our test university (the model being platform-independent). The plugin is named EGbKST (Educational Goal based Knowledge Space Theory) and has a dynamic interface for learning (*cf.* Figure 3) and a visualization interface of its results that is visible only at the request of the learner (not presented here). Learning is organized in dynamic blocks (Communication, Statistics, Resource, Goal and Activities) whose content and visibility depends on each learner and their knowledge state.

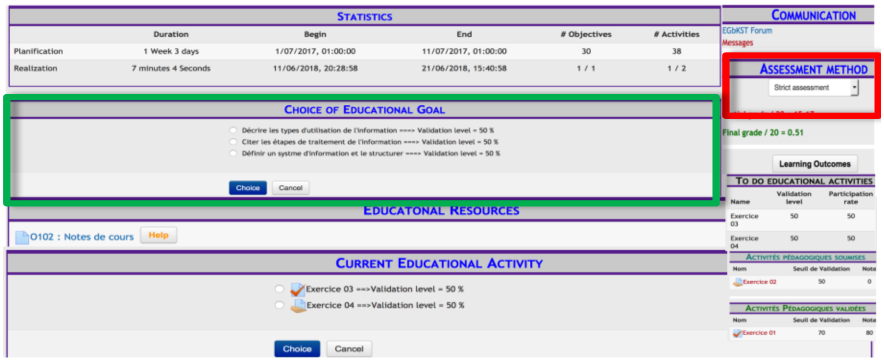

Figure 3. Learning interface

The learner initially chooses a goal to achieve (block in green). As soon as it is reached, the system offers them a new set of goals they can achieve and so on. The learning ends when the learner has achieved all the goals. The goals and the order in which they are chosen represent the scenario built by learner. The system allows to change current goal to choose another one if necessary. To progress in learning, the learner has a list of assessment modes (block in red) to choose from to express their desired degree of challenge. The efforts made and the chosen mode allow it to progress at a higher knowledge state.

So, we answered positively to our first research question, proposing a model that allows learners to co-construct their learning scenario.

5. ASSESSING CO-CONSTRUCTION OF SCENARIO BY LEARNERS

5.1 Methodology

The experiment was realized in 3 phases in a public university in sub-Saharan Africa, with nearly 3500 students enrolled in 21 academic sections and 120 teachers in 15 specialties (from bachelor to doctorate).

Phase 1: Assessing the acceptability of the model by the learners. To answer our second research question, we submitted a survey to students (https://goo.gl/forms/EgiVdEgE1z8mfFQr1). The survey questions are in affirmative form with responses on a 4-point Likert scale extending from "strongly disagree" to "strongly agree". The survey collected student opinion on the following aspects: (1) Current educational model: the question is to find if they find that (a) the courses have clearly defined and identifiable educational goals, (b) for the defined goals, do they have learning resources and activities to evaluate them? (c) can the learning be done in a different order than the teacher's? (2) Interests for a goal-based educational model: the question is to know if they think that a such model would facilitate their learning and success. The questionnaire was sent to all 3500 students, but we received only 85 responses (Consulted at 11-24-2017). This can be explained by the fact very few students are trained to take online courses (around 250 students have access to online training platform). Participants come from 14 academic sections and 3 teaching cycles. Their age varying between under 18 years to over 45 (M = 21.60, SD = 6.46). 80% of survey responses are from learners who have been trained in the use of online learning platform.

In view of the response rate, these results should be taken with caution, because it probably over represents certain categories of students (*e.g.* motivated, technophiles). To counter this potential bias, we also asked those questions to the 11 students who tested the system (*cf.* below).

Phase 2: Assessing the usability of the system. We tested the usability of our system during a real-life experiment on the "General Political Economy 1" teaching unit taught in the 1st year of the Legal Sciences academic section for 2 ECTS credits. Students (N = 11) are professionals in continuing training whose age vary between 24 to over 50 (M = 36.22, SD = 6.38). To carry out this experimentation, the teacher agreed to adapt his course according to our model (29 learning goals, 33 learning resources, 31 learning activities and a teacher-recommended scenario). Learning takes place over 2 weeks. The resources are a mix of files, hyperlinks and videos. The activities are of the production type and quiz (true/false, yes/no, matching, single choice and multiple choice). The experience is organized in 2 stages. Stage 1 took place in a 2-hour classroom session during which we explained to learners and tutors how the new teaching model worked. Stage 2 consisted to learn online under supervision of tutor.

Phase 3: Assessing the learning satisfaction of the learners. At the end of the course, learners filled a survey (http://foad.uasz.gouv.sn/mod/questionnaire/view.php?id=5274) evaluating their satisfaction with the new learning model. The survey questions are in statements with a 4-point Likert scale (from "strongly disagree" to "strongly agree"), focusing on the perceived impact of the model on ease of learning and contribution to success.

Assessment of the model acceptability (phase 1) is done with the Google Forms tool, with data saved in a CSV (Comma-Separated Values) file. During learning (phase 2), learner interactions with the system are recorded in a plain text log file in which each line contains a quintuplet (date, action, object, score, learner), corresponding to the action done by a learner on a learning object. The data (CSV file) of the learning satisfaction (phase 3) are collected from the Moodle platform of training.

To validate our third research question, we considered 2 indicators: diversity of scenarios and of assessment modes. **The diversity of scenarios** allows to determine if co-constructed scenarios are different. For each learner, we extract successive learning goals followed in chronological order. For those who have not completed their learning, we compare their learning sequence with the corresponding sequence in the reference teacher-recommended scenario (*e.g.* the first 5 steps for a learner who dropped out after 5 steps).

The diversity of scenarios is represented by the number of different scenarios and the distance between alternative scenarios (distance based on the Levenshtein distance - when computing distances between scenarios, we only consider sequences of identical length). **The diversity of assessment modes** allows to determine the willingness of each learner to progress according to the mode chosen at each learning stage. This indicator is broken down into 2 sub-indicators: the percentage of time that each assessment mode is used to progress, and for each mode, the number of learners who used it and the number of times used.

5.2 Results and Discussion

5.2.1 Acceptability of the Model by the Learners

The acceptance of the model is assessed in the general framework with all 85 respondents. We present below the results and then contrast them with the results obtained with the 11 students involved in the experiment.

Current educational model. The survey shows that the courses are organized mainly in chapters (81.2%) and often in parts (32.9%). 27% of participants estimate that certain learning goals do not have learning resources clearly associated to them. 3.5% of participants believe that in some courses, goals are not announced. Results are more concerning for exercises, for which 50.7% learners estimate that educational goals are not assessed. This finding justifies our approach to associate resources and exercises with each goal to better structure and facilitate learning. 70.6% of participants' estimate that the course could be better learned with a different scenario than the one imposed by the teacher. We conclude that current educational model contains weaknesses identified by learners and their wish reinforces our approach of co-construction.

Interests of pedagogical model based on goals. 81.2% of learners estimate that learning would be easier if it is organized and presented by goals and not by chapter. 91.8% of them believe they would obtain better results if they were assessed by goal. The results obtained from the 11 students of our experiment are similar to those obtained on the larger sample. The only difference is the availability (online) of resources and activities for the goals. This difference is justified by the fact that online course procedure requires the availability of resources and activities for each learning sequence.

We thus can respond positively to our RQ2: our approach seems in agreement with learners' expectations.

5.2.2 Scenarios Diversity

To visualize different scenarios followed by the learners, we represented each stage of the scenario of each learner with a different color (with gray corresponding to identical steps in teacher-recommended scenario – *cf.* Figure 4). We can see that the learners have built 4 of 11 possible scenarios (called call A, B, C and D), where scenario A is built by 72.7% of learners (*cf.* Figure 5) and corresponds to the one recommended by the teacher. We think this high preference rate is related to a system bias, because the proposed goals for the choice appeared numbered. Therefore, it seems normal that learners chose the natural order (increasing) of goals when they did not have strong preferences. The distance between the scenarios shows that scenario C (resp. D) is the most distant (resp. close) to the recommended one (*cf.* Figure 6). These results show that when giving choice to the learners to build their own scenario, they can build a variety of logical scenarios while respecting to pedagogical constraints. It should be noted that possible variability of the scenarios was limited by the fact that the teacher had chosen to impose the order of chapters. For example, it was not possible to move to a goal in chapter 2 as long as all the learning goals of the first chapter were not validated.

Figure 4. Visualization of 4 scenarios built by learners

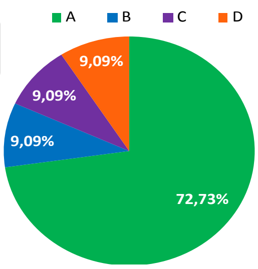

Figure 5. Representation of learners by scenario

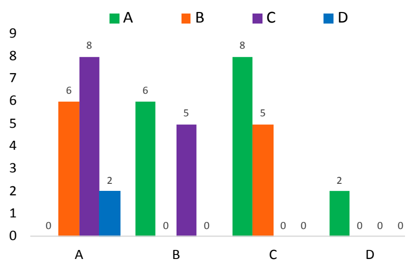

Figure 6. Levenshtein distance between different scenarios

5.2.3 Assessment Modes Diversity

Although the strict mode is the most difficult, we found that all learners used it more than 75% of the time (*cf.* Figure 8). This mode is selected by default at the beginning of learning, which can justify that all learners are assessed in this mode at least once. Nonetheless, the number of times used shows the desire to remain in this mode. This point of view is reinforced by a manual trace analysis which reveals that certain learners (*e.g.* L05 and L09 in Figure 7) return to certain activities to improve their score to stay in this mode. Except for 4 learners (*cf.* Figure 7), we find that they are challengers (learners who like to validate all activities without compensation). We think that once the learners have changed the assessment mode, they want to progress quickly and therefore preferred the flexible mode over the restrictive one. We also find that all learners who changed their mode stopped some time after and did not view all the educational content. This could mean that changing to flexible mode indicates future dropout, and that could be brought to the teacher's attention.

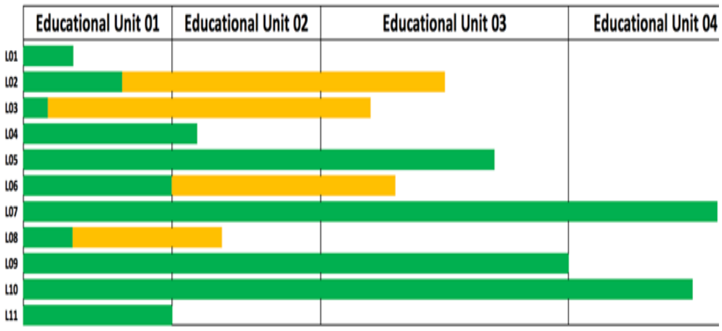

Figure 7. Scenario representation of each learner by assessment mode (Strict mode in green; Flexible mode in orange)

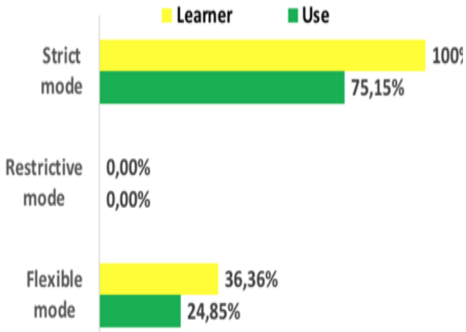

Figure 8. Representation of learners and progress number by assessment mode

5.2.4 The Learning Satisfaction of the Learners

54.5% (6 of 11) of learners answered to the post-study survey (4 of them reached the third learning unit). 50% estimate that their learning was facilitated by the initial goal announcement. 66.7% thought the course presentation by goal (*vs.* by chapter) facilitated their learning, confirming the value of our approach which propose to structure a course by goal to facilitate its accessibility. 50% said they liked choosing their learning path because they are central actors of their learning, confirming our observation that the diversity of scenarios is well appreciated and used. However only learner L07 explicitly declared thinking his success was related to our approach. Conversely, learner L02 said: "*This software causes a lot of problem because my progress was very slow. The internet connection caused me great prejudice. (...) I propose to let us continue with the old method.*". The main reason is that our approach requires frequent connection to assess their learning to unlock the next learning content, which can be an issue in the sub-Saharan African context.

5.3 Analysis for Reengineering

This experiment revealed system weaknesses to correct to avoid bias in the analysis of learners' behaviors.

Bias when constructing a scenario. To correct it, we will hide goal numbers and instead present for each goal metadata such as duration, validation threshold, description, the number of resources and activities. This change should allow for a greater diversity of scenarios and more meaningful choices.

Decision between challenge and progression. We realized that some learners stay on strict assessment mode while they are not progressing. We propose to find a mode that allows them to progress and recommend it. This decision is made because we think some learners forgot they could change their mode.

Choice of assessment mode. To avoid a default mode, we will explicitly ask learner to choose their assessment mode at the beginning of the learning.

Risk of school dropout. Whenever the learner changes their assessment mode to a less challenging mode, we will notify the teacher and ask the learner, the reasons of change to better understand their motivations.

6. CONCLUSION

Giving learners the opportunity to build their scenario while learning, making them a main actor of its co-construction, is not really considered in recent research in TEL. Our model shows that it is possible, and that the built scenarios respect educational constraints defined by the teacher. Experiments led with teachers and learners show their satisfaction and the ability of the model to improve both the learning and teaching processes. The diversity of scenarios built by learners revealed that some learners seem to prefer a different approach than the teacher's default one. Moreover, the model offers learners to modify their assessment mode at any time. Their desire to be challenged (strict mode used more than 75% of the time) is a sign that our model offers a motivating framework to better acquire competences. This is confirmed by the fact some learners returned on previous activities to improve their score to remain in a strict assessment mode. We observed that some learners prefer the challenging mode, even if it slowed down their progress. To avoid drop-out, we plan to identify this indicator moment and recommend using a less challenging mode.

Among the limits of this work, the context of our experimentation (few online learners in sub-Saharan Africa) does not allow us to fully validate our approach – integration to a MOOC could help reaching a more reliable conclusion. Moreover, our model is only applicable for learning by competences or educational goals. A first analysis of learning traces allowed us to define reengineering axes, which will give us more accurate learning tools and highlight the existing ones.

In future work, we will integrate into the model the analysis of the chosen scenario and present it to the learner. When they face difficulties while diverging from the reference scenario, we may redirect them towards the reference scenario. Moreover, traces analysis over several courses could help in identifying patterns and thus learner profiles and learning indicators that will help us to guide or redirect future learners.

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