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# Generation of pencil and paper exercises to personalize learners' work sequences: typology of exercises and meta-architecture for generators

Marie Lefevre, Stéphanie Jean-Daubias, Nathalie Guin  
Université de Lyon, CNRS  
Université Lyon 1, LIRIS, UMR5205  
F-69622, France

{Marie.Lefevre, Stephanie.Jean-Daubias, Nathalie.Guin}@liris.univ-lyon1.fr

**Abstract:** In the context of personalization of learning, we present our approach and both theoretical and practical results of our research allowing teachers to propose personalized work sequences to their students. We established a typology of pencil and paper exercises that can be given to learners. Here we propose a meta-architecture for semi-automatic generators organized in four levels, meta-architecture applied to establish the architectures of the required generators to propose the exercises of our typology. We also implemented and tested these architectures in a module allowing to generate pencil and paper exercises sheets suited to learners profile.

**Keywords.** personalization, generation of exercises, architecture, genericity.

## Introduction

This paper concerns personalization of learning that is one of the major issues of Technology Enhanced Learning. Personalization central objects are learners profiles, which gather information about the learners, thus allowing to describe their knowledge, skills, perceptions and/or behaviors. These data are collected or deduced from one or several pedagogical activities, computerized or not (Jean-Daubias and Eyssautier-Bavay, 2005).

Our approach consists in helping the teacher proposing to learners personalized pedagogical activities suited to their knowledge and gaps shown in their profiles, and suited to the teacher's needs and to the pedagogical context, expressed in what we name *pedagogical strategies*. To personalize pedagogical activities offered to the learner based on their profile, we can either use knowledge-based systems to generate the pedagogical activities best-suited to the profile, or provide the teachers with tools allowing them to perform this task themselves. In our research we link these two options.

In this paper we focus on the generation of pencil and paper exercises part of our research: from the corresponding theoretical propositions to their implementation within the *Adapte* module. We first present the context of our research within the *PERLEA* project and its software environment. We then focus on the generation of exercises part in the *Adapte* module. To build this module, we first proposed a typology of exercises that can be given to a learner, together with a meta-architecture and the architecture of eight generators able to create all of these exercises. We detail these two aspects before moving on to their implementation and validation. We illustrate our presentation with a running example: from teachers needs to the solution proposed by *Adapte* (we thus present the teachers interface and examples of exercises sheets produced for different learners).

## Scenario of utilization

A teacher uses in his classroom an ILE on biology with his eight-year-old pupils. At the end of the learning session, this ILE generates a profile for each learner. In addition, the teacher organized for all of his students the national assessments due in the beginning of year. These assessments produced a report of achievements, mistakes and difficulties of each pupil in mathematics and French. Thus, for each pupil the teacher has several profiles from different sources, ILE and pencil and paper, for several disciplines: the computer generated profiles from the ILE about biology and the pencil and paper profiles for mathematics and French corresponding to the results of the national assessment. The teacher wants to use these profiles to provide each pupil with personalized exercises sheets: for example exercises in biology for learners who encounter difficulties in the use of the ILE, additive word problems for those who made errors in this part of the mathematics test, conjugation exercises for students who had such problems in redaction parts, and addition and multiplication tables depending on the detected errors. These sheets enable learners to be self-reliant in several disciplines when working.

Currently, teachers cannot adopt this approach easily. Actually, there is no existing tool that would enable teachers to use data from ILE externalizing their learners profiles, or to link this data to the pencil and paper profiles

they themselves managed. Moreover, teachers can produce personalized exercises sheets but then they either have to create exercises themselves, or take existing exercises and manually adjust them to their needs and working methods. They also have to decide for each student which exercises to put in his or her sheets. This work requires a great involvement from the teacher.

### **Context of our research**

The PERLEA project aims at improving the integration of ILEs in education by building bridges between the use of ILEs and teachers' everyday practices. To do so, we are interested, in a generic way, in learners profiles and their *a posteriori* use for the management of learners and the personalization of learning (Jean-Daubias and Eyssautier-Bavay, 2005). Hence we aim at developing an environment that would permit teachers to manipulate existing profiles. This environment consists of two phases: the integration of existing profiles (based on PMDL, the profiles modeling language that we proposed to unify external learners profiles to permit their reuse, either pencil and paper or software ones (Eyssautier-Bavay et al., 2009) and the management of thus unified profiles.

In order to explain this mechanism, we go back to our example. Reusing profiles requires knowing their structure. The teacher defines a unique profiles structure describing the information contained in the two types of profiles for the three disciplines: the profile of the ILE on biology and the pencil and paper profile in mathematics and French. Next, the teacher specifies to the system how to automatically convert ILE profiles to get the biology data, and inserts information on mathematics and French by keying them. At the end of the integration phase, the teacher has a unique profile for each of his students gathering all information in the different disciplines. The second phase of the environment proposes rich uses of the unified profiles. One of such uses is accomplished by the *Adapte* module, which offers to learners activities adapted to their profiles. These activities may be worksheets generated by the system or computerized activities to be done in an external ILE. For pencil and paper activities, *Adapte* generates worksheets matching each learner profile. To achieve this, it creates tailor-made exercises to be included in the sheets and determines the length of the worksheets themselves. It also provides the teacher with the answers to the exercises contained in the sheets. In the case of computerized activities, *Adapte* sets personalized sessions on external ILEs according to the learners profile. For this, it uses ILE exercises generators or chooses exercises in the ILE database. It also computes the number of exercises, in which order they appear and the duration of the session.

### **Generation of pencil and paper activities**

For *Adapte*, a pencil and paper activity is a worksheet to be printed. The exercises on the sheet can relate to several disciplines, whatever school grade they are used in. We will therefore explain how we have done an inventory of exercises proposed to learners by teachers of all subjects in elementary, secondary and high school. Finally, we show how we have implemented a software able to generate these exercises, using existing generators when available.

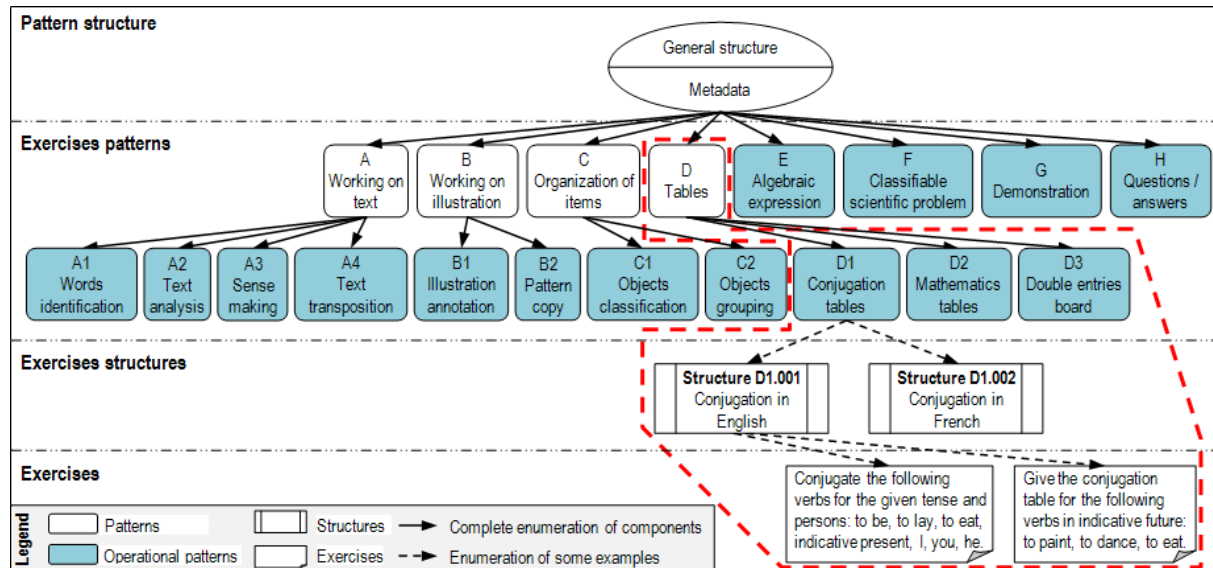
#### **Typology of exercises**

By studying curricula published in the official texts of the French Ministry of Education, and subsequently working with teachers in elementary schools, as partners in the PERLEA project, we have identified fifteen types of exercises that can be proposed to a learner, taking into account all subjects and levels. The identified typology of exercises is presented in Figure 1.

Let us go back to our example. The teacher wants to create exercises so that his students can work on additive word problems, on addition and multiplication tables and on conjugation. For example, to get conjugation exercises, he selects the pattern "Tables" (see D in Figure 1), then refines his choice by selecting the operational pattern "Conjugation tables" (see D1 in Figure 1). From this operational pattern, the system presents the teacher with an interface enabling him to specify the constraints on exercises generation. At this particular point, the teacher specifies the language, possibly the tenses, the persons, the number of verbs to propose, etc. He can also specify priority verbs. All these constraints are saved in an exercises structure (see Structure D1.001 in Figure 1). Then, from this exercises structure the system will generate the exercises contained in the personalized worksheets. Thus it will generate different exercises from the same exercises structure.

More formally, our typology contains eight exercises patterns (A to H in Figure 1), some of which can be split into several operational patterns. An *exercises pattern* (e.g. D - Tables in Figure 1) defines a category of exercises generated with the same exercises generator. An *operational pattern* (e.g. D1, D2, D3 – conjugation tables, mathematics tables, double entry boards) specifies a subset of exercises generated through the pattern generator (here D), but with particular generation constraints. Our typology contains fifteen operational patterns

defining fifteen types of exercises (A1 to D3 and E to H). The generic structure of these patterns and the set of metadata common to all patterns are defined in a *patterns structure*. From there, creating an *exercises structure* consists in associating an operational pattern with generation constraints. Creating an *exercise* consists in assigning to the parameters of the exercises structure values that satisfy these constraints. Thus created exercises are composed of elements of wording and elements of answer proposed to the learner, as well as the solution to the teacher.



**Figure 1: Typology of pencil and paper exercises**

## Generation of exercises

We present here how the system generates exercises corresponding to the eight exercises patterns identified in our exercises typology (see A to H in Figure 1). We show how we considered reusing existing generators in our system and how we developed a meta-architecture that we then specialized for generators useful to Adapte.

In Adapte, we incorporate semi-automatic generators (Jean-Daubias et al., 2009) since they create a large number of exercises and permit the personalization of their generation. The problem is to know whether this is possible or not for all the exercises patterns we have identified. For example, providing a semi-automatic generator for the creation of a Multiple Choice Questions test, for all domains and all levels, appears unrealistic. Indeed, this would require using very large knowledge bases to cover all disciplines and levels of education. A compromise is to offer the teacher a manual generator enabling him to provide the knowledge base for an exercise (a set of questions with several choices for each). Then, the system would choose several questions and answers, replacing some words by equivalent terms to diversify wordings. This solution allows, for the same exercises structure, to generate various MCQ tests: they will have no more than a few questions in common, and for them, they will not necessarily have the same proposed answers. We use this approach, which relies on the teacher to provide the semi-automatic generators knowledge bases, in cases where state of the art semi-automatic generators seem unrealistic in our generic context.

Having chosen to use semi-automatic generators, we then studied the possibility for each Adapte exercises pattern to use existing generators. If we except the F-type of exercises in Figure 1, with the generators which were available to us, the teacher has either to key in the exercises completely or he cannot influence at all the creation process. Using such type of generators would have prevented us to propose a random option to teachers in the generation of their exercises. For categorized scientific problems (F-type in Figure 1), we integrated into Adapte, GenAMBRE, the generator of AMBRE-Teacher (Guin-Duclosson, 1999), implemented to create arithmetic word problems in the AMBRE-add ILE. By providing the necessary knowledge bases, this generator could be used in a generic way and thus provide exercises on problems of combinatorial analysis, thermodynamics, etc.

### *A meta-architecture for semi-automatic generators*

To each exercises pattern presented in Figure 1 corresponds a generator that creates exercises for the learner and answers for the teacher. An answer will be either defined by the generator when possible, or keyed in by the teacher. Similarly, if some constraints are not specified by the teacher, they will be specified by the system.

Moreover, when an exercise is generated, the exercises structure may contain constraints of re-generation to prevent the same exercise to be generated again for the same exercises structure. All generators proposed for Adapte comply with a generic architecture (see Figure 2) that we will detail before giving two examples.

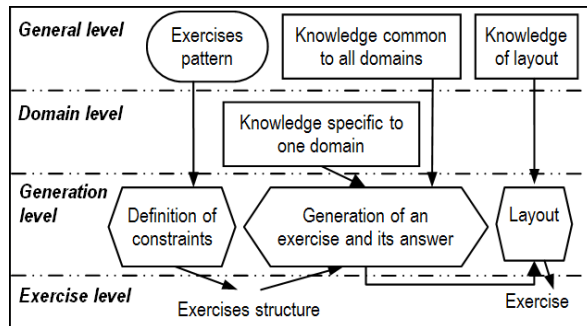


Figure 2: Meta-architecture of exercises generators

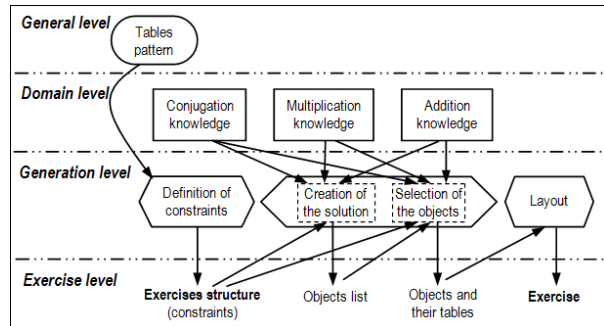


Figure 3: Architecture of generator for "Tables"

Thanks to this generic architecture of exercises generators, we can specify four levels. The *general level* contains the knowledge common to all domains for which we want to generate an exercise, e.g. the knowledge required to write a statement in natural language. The *domain level* contains the knowledge specific to the domain, e.g. the knowledge of calculation. The *generation level* contains the specific processes to create an exercise: definition of constraints on an exercises pattern saved in an exercises structure; instantiation of this structure to generate an exercise and its answer; layout enabling to provide exercises with a uniform presentation. Finally, the *exercise level* contains all the documents for the created exercise, including the exercises structure and its instantiation (wording of the exercise and its answer).

#### Generators architectures

We specialized the meta-architecture to define the exercises generators associated with the exercises patterns except for the Demonstration pattern. To illustrate the genericity of this meta-architecture, we explain how we applied it to the tables generator (see Figure 3) and to the categorized scientific problem generator (see Figure 4).

To generate tables the system uses the corresponding exercises pattern and the domain knowledge (conjugation, multiplication and addition knowledge). Before the generation, thanks to an adapted interface, the teacher specifies the generation constraints that will be saved in the exercises structure. The generator provides the exercise and its solution. Finally, a layout phase standardizes the presentation of the exercises.

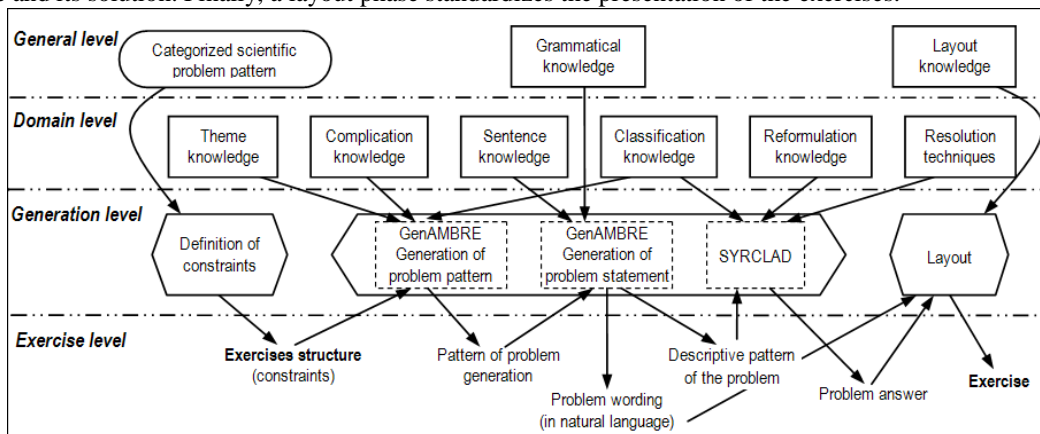


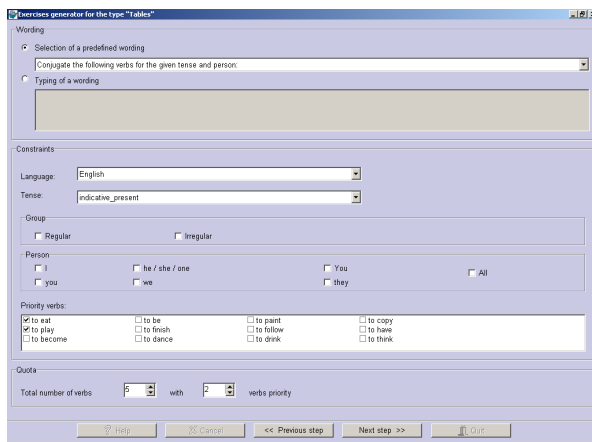
Figure 4: Architecture of generator for "Categorized scientific problems"

Let us take a second example. Categorized scientific problems, which can be found in scientific academic subjects (mathematics, physics, chemistry...), are based on classes of problems. We expect the student to solve the proposed problem by identifying its class. For example: "We have a pack of 32 cards. We take 5 simultaneously. How many draws contain exactly 2 knaves and 2 hearts?". To generate this type of exercises, the system has the

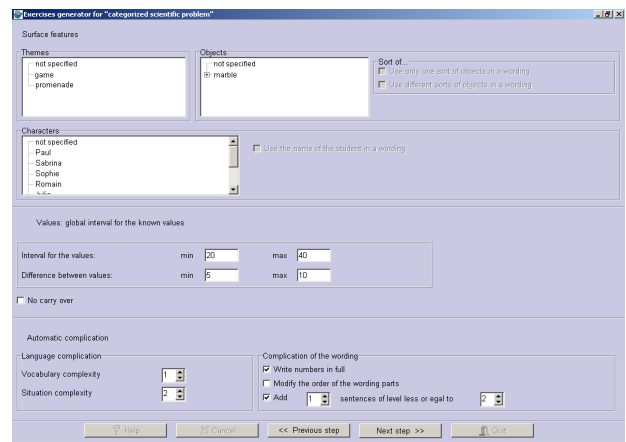
exercises pattern corresponding to it, the knowledge of general level (grammatical knowledge, layout knowledge), as well as the domain knowledge (knowledge on the sentences, their theme and the possible complications of wording; knowledge of classification, reformulation and problem-solving techniques that enable the system to solve the problem). Before the generation, thanks to an adapted interface, the teacher specifies, the generation constraints that will be saved in the exercises structure. The creation of the exercise uses the GenAMBRE generator (Duclosson et al., 2005) then the SYRCLAD solver (Guin-Duclosson, 1999) to provide a solution to the proposed problem. Finally, a layout phase standardizes the presentation of the exercises.

## Implementation

These architectures are implemented in the Adapte module. To create an exercise, the teacher has first to choose the corresponding type of exercises on the screen presenting the different exercises patterns. This screen matches our typology of pencil and paper exercises presented on Figure 1. For example, to create conjugation exercises, the teacher chooses the tables pattern and the conjugation operational pattern.

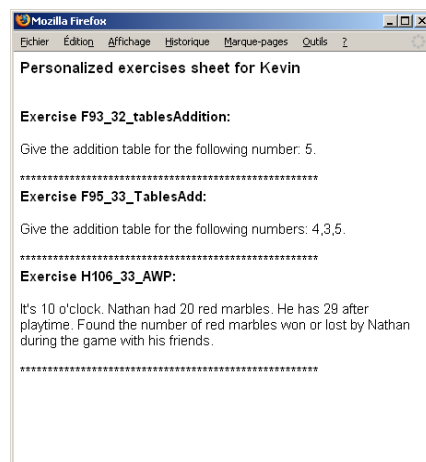
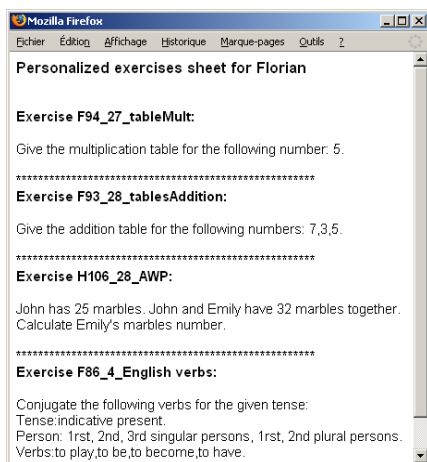


**Figure 5: Definition of constraints for the “conjugation” operational pattern of Adapte.**



**Figure 6: Definition of constraints for the “categorized scientific problems” operational pattern.**

From this operational pattern, the system presents the teacher with an interface enabling him to define the constraints of exercise generation (cf. Figure 5). The teacher chooses a language at this point (English in our example) and if necessary specifies the tense (indicative present in the example), persons (random in this example), types of verbs (regular or irregular for English language) and/or verbs (to eat and to play are priority verbs in the example), and the number of verbs to be proposed to the learners (for example 2 priority verbs among 5 verbs, in that case all learners will have to conjugate the 2 priority verbs, plus 3 other verbs, differing according to learners).



**Figure 7: Example of exercises sheets generated by Adapte.**

All these constraints are saved in an exercises structure, described with metadata to facilitate its reuse. The system generates the exercises contained in the personalized worksheets from this exercises structure. Thus it generates different exercises from the same exercises structure (cf. Figure 7).

Let us come back to our example. The teacher will define with *Adapte* exercises structures in additive word problems, conjugation and addition and multiplication tables. For each type of exercises he will choose the corresponding exercises pattern and then specify the constraints (cf. Figure 5 for conjugation and Figure 6 for additive word problems). *Adapte* will generate problems corresponding to the teacher's specifications and suited to learners difficulties according to their profiles. Figure 7 shows examples of exercises sheets generated for two different students: Kevin has only difficulties in mathematics so he has 2 addition exercises and an additive word problem; Florian has in addition conjugation difficulties, so he has also conjugation exercises.

## Conclusion

As a solution to the problem of personalization of learning, we established an approach helping teachers to propose pedagogical activities suited to learners' knowledge and to teachers needs. In this framework, we focused here on the generation of pencil and paper exercises.

First, we presented our typology of exercises that can be given to a learner from primary school to high school. This typology includes fifteen types of exercises. We defined it with the primary school teachers associated to the PERLEA project. To test its scope, we have worked with secondary teachers. We observed each of the exercises they use for their French, English, mathematics, biology, history and geography classes for all levels of secondary school. All the exercises used were in our typology. Now, we have to work with experts in educational science to completely validate our typology, both in its genericity and its completeness.

We then proposed a generic architecture of exercises generators and set the architectures of the eight exercises generators that we considered necessary to create exercises of our typology. These generic architectures can be used to develop exercises generators whatever context they are meant to be used in. If these architectures facilitate the setting up of generators in new domains of application, the considerable work of instantiation of knowledge bases for a new domain still remains unavoidable. We were able to test the genericity of these generators by implementing some of them in varied domains (e.g. we have implemented the tables generator to propose conjugation exercises but also multiplication or addition ones).

Then, we developed *Adapte*. The module design was made in partnership with teachers and, the software being now usable, we have submitted it to these same teachers and to a teacher outside the PERLEA project. Until now all their feedbacks seem to validate the software and its design. The system is usable and permits teachers to define the constraints allowing to generate exercises matching their needs and their learners' knowledge. We must now make a more rigorous evaluation. This evaluation will be conducted with experiments with more teachers unrelated to the conception of the module. These experiments will involve all concerned modules of the PERLEA project environment, and range from the definition of a profiles structure by the teacher to the effective use of personalized activities by learners.

In the continuity of this work, we are presently finishing the implementation of the *Adapte* part that offers sessions suited to learners' skills on an external ILE (Lefevre et al., 2009).

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