Helping Teachers Generate Exercises with Random Coefficients

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Abstract: First, we propose two taxonomies concerning software designed for teaching mathematics, which we call TEL (Technology Enhanced Learning) environment, the first one is on teacher's place and role in TEL environments, the other one is on the activities which are foreseen and provided by TEL environments. Second, we consider TEL environments which provide teachers with tools for building patterns of exercises used in the TEL environment to generate randomly and dynamically exercises or list of exercises. Our approach is compared to classical approaches (based on standards like IMS-QTI or on Computer Algebra Systems).
Keywords: Design of TEL environments, Training and Test activities, Pedagogical and Didactical Parameters, Pattern of exercises

Introduction

Since 2000, we are working on the TEL (Technology Enhanced Learning) environment Aplusix dedicated to the teaching and learning of formal algebra at secondary school level.
During a first phase, from 2000 to 2003, most of our work has been devoted to the design of a microworld for *learning by doing* elementary algebra [NIC-04]. Main principles used to develop this environment were, first, to let students freely and intuitively build and transform algebraic expressions, as they can do on paper, and second, to give permanent but not intrusive epistemic and fundamental feedbacks on the syntactic and semantic correction of the reasoning followed by the students.
The second phase, from 2003 to 2005 introduced a shift in the kind of TEL environment we were working on: we moved from the microworld paradigm to an exerciser paradigm. We worked specifically for teachers, trying to provide them with tools for managing and improving or facilitating their work.

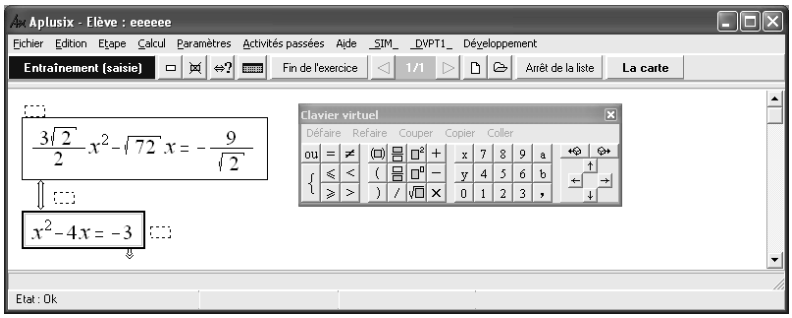

Figure 1: First step of reasoning in Aplusix, further steps should follow to achieve a solution.

In particular, we added to Aplusix a map of exercises which is a set of about 40 families of exercises based on didactical variables and organized by type of exercise and level of difficulty. Each family contains about 10 patterns of exercises having variables for the numbers and constraints to be satisfied. The exercises are generated from patterns by non trivial random choices of the numbers and verification of the constraints; see [BOU-05].
The families of exercises and the patterns of exercises used in the map of exercises have been built by didacticians in mathematics and an important work has been made with them to define the language used for patterns. Each pattern is an object with a dozen of attributes (ex: the pattern itself with parameters, the domain for the value of parameters and constraint to be tested out to validate an instantiated exercise, mean time to solve the exercise, exercise type, hints to describe the pattern, general family of pattern, pseudo-frequency to set the number of apparition of the pattern).

Our work for helping teacher on the automatic generation of random exercises have been the occasion to make short studies about the teacher's place and role in TEL environments and the activities which are foreseen and provided by TEL environments. The first part of this communication will be about these two taxonomies.
The second part of our communication will be at the cross point of the two taxonomies, and considers TEL environments which provide teachers with tools for building patterns of exercises and generating randomly and dynamically list of exercises. Our approach, and the last developments of our work, will be compared to other typical and standard approaches.

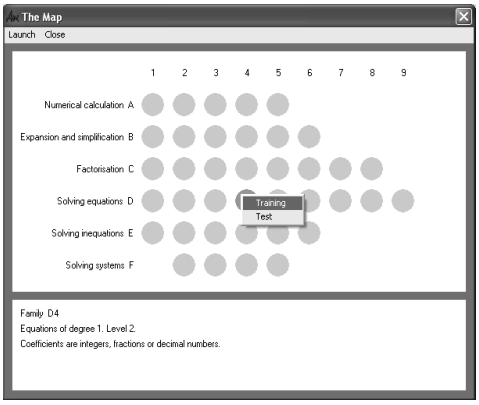

Figure 2: The map of exercises. When the student clicks on a point, s/he gets a description of the family in the bottom part and a menu for launching the family in the training or test mode.

Taxonomies

Teacher's place and role in TEL environments

The first short taxonomy considers teacher's place and role in TEL environments. The goal is to observe particularly if specific parts of TEL environments have been designed for the teacher, and if the answer is yes, what are theses parts. With these questions in mind, four groups can be described (from less to most place and role):

- **T1. TEL environments that simply ignore teachers.** None part of the TEL environment has been designed for teacher's use specifically. None functionality is devoted to the teacher. It does not mean that teacher has no role in the use of the TEL environment, because it does not mean that the TEL environment acts as a teacher. Two subgroups may be defined for that group, the first one (T1.1) where the TEL environment supposes the presence of a teacher which has to organise the activities (a lot of microworlds belong to that subgroup), the second one (T1.2) where the TEL environment incorporates an electronic teacher (most of ITS – Intelligent Tutoring Systems- belong to that subgroup).
- **T2. TEL environments that give feedbacks to teachers.** Some TEL environment from the previous subgroup T1.2 can give feedbacks to teachers, for example a user model, or a historic of the student's actions. In that case, the part of the TEL environment consists essentially in showing externally the internal representation of the students (T2.1).
  Some TEL environments have been specifically designed to give feedbacks to teachers (T2.2), for example some TEL environment are dedicated to *competencies diagnosis*. Frequently, TEL environments from that subgroup (T2.2) are not used in class during normal time and their use is very limited. So that subgroup is very small, in most of the case, when a TEL environment gives feedback to teachers, it belongs to one of the two last groups.
- **T3. TEL environments with teacher's interface to manage classes.** The role and place given to teachers is limited to manage their classes, students and activities (among predefined activities) and, sometimes, to specify the behaviours of the TEL environments with pedagogically and didactically meaningful parameters. The limitation occurs when the teacher

want to modify the activities predefined in the TEL environment. The main difference between T3 and T4 is the possibility to add new exercises.

- **T4. TEL environments teacher's interface to manage classes and edit activities.** These are TEL environments that propose teachers to manage their classes, students and activities, to specify the behaviours of the TEL environments and to easily modify or enrich the TEL environments with their own activities (lessons, exercises, tests) without noticeable competencies in computer science. This means that the TEL environment must include very specific part and functionalities to permit the introduction or edition of one core part of the TEL environment. It does imply, first, an important supplementary work for the TEL environment's designers, second, an important supplementary work for teacher. Clearly, in that case, the teacher has to learn how to use that specific part of the TEL environment. It is worth noting that this specific part is very often delicate and complex. Next, the teacher has to effectively introduce or change the activities. It does mean that, compared to the paper and pencil environment, teacher's work for preparation may be greater than before.

From T1 to T4, teacher's role and place in the environments increase. Hopefully, it does not necessarily means that, from T1 to T4, the use of TEL environments is heavier for teachers. In a certain extent, TEL environments from T4 could be used as microworld like in T1 without a huge implication of the teacher. The questions arisen here about the importance of teacher's competencies and implication are important when we consider usability and the chance for TEL environments to be adopted and used

From a set of 21 TEL environments selected for a study in the research community [TEL-06], and in the most advanced commercialised TEL environments, we have found out 5 TEL environments belonging to T1, 4 belonging to T2, 5 belonging to T3, 7 belonging to T4. This is not necessarily representative of all TEL environments designed and used. We think that our study privileged rich TEL environments.

Activities foreseen and provided by TEL environments

The second short taxonomy is about the activities which are foreseen and provided by TEL environments. We point out technical and technological competencies needed for these activities and compare these activities done in TEL environments contexts with similar activities accomplished without computer in the regular work of the classes.

From a global point of view three main activities are considered:

- **Lessons**. From our point of view (TEL environments design and development), the organisation of such activities is not the most difficult one. Modern programming languages offer components which permit to display multimedia documents with texts, mathematics, images, videos… The most difficult part related to that activity does not concern designers and developers of TEL environment but people – teachers, didacticians or mathematicians – who define and create the content of such documents. The work related to lessons and the way lessons are performed is not specific to TEL environments, it is analogous to the one done without computer.
- **Training activities**. From our point of view, training activities introduce important works for designer and developer of TEL environment but consequently allow added-values in comparison to classroom without computer activities, for example: feedbacks, hints, randomly generated exercises… Difficulties come from the necessity for the TEL environment to tackle the complexity of mathematics. One solution consists to link the TEL environment with CAS (Computer Algebra Systems) and to rely on CAS for all the mathematical questions, but it is not clear that this solution is the best one. We subscribe to the controversies about the ability of CAS to be the mathematical expert of a TEL environment [PRA-01]. Another solution is to reduce the training activities to multiple choice questions, or activities without any added-values, depending on the teacher for feedbacks, hints and creation of exercises.

If we focus on the feedbacks provided during training activities when students have to practice with exercises to acquire techniques and automatisms, we have already pointed out for Aplusix the two fundamental feedbacks, the first one concern the equivalence checking, the second one concern the validation of the end of an exercise. The difficulty is that minor pedagogical and didactical elements interfere with major and essential mathematical elements.

- **Test activities**. Test activities necessitate also important works for designer and developer of TEL environment but consequently allow added-values in comparison to classroom without computer activities, here, for example: automatic mark and diagnostic… Difficulties do not concern mathematics but essentially didactics and pedagogy and cannot be solved by general didactical or pedagogical software solutions, because there does not exist any one.

On top of these activities, we must notice, also, the need for functionalities in TEL environments for managing and sequencing the execution of such activities; fortunately, there exists some general solution for defining and playing scenarios composed of such activities.

Building patterns of exercises

The second part of our communication is at the cross point of the two previous taxonomies, it considers TEL environments which provide teachers with tools for building exercises or patterns of exercises in the TEL environment to generate randomly and dynamically list of exercises for training activities. Three solutions can be observed:

- **Pedagogical Web Standard approach.** We have to look at the standards like IMS-QTI [IMS-04]. The advantage targeted by the use of such solution is to gain compatibility and possible interoperability. The first main problem is that pedagogical standard like IMS-QTI does not know a lot about mathematics. To some extent, this is not so important when the only training activities concern multiple choice questions. But for open exercises, this could appear to be a major inconvenient. Some tentative exists to introduce Mathematics in standard [MathQTI]. The second main problem is that this approach necessitates that the teacher willing to introduce new exercises, or pattern of exercises, must be familiar with the languages used like IMS-QTI, IMS-SS, IMS-LD, IMS-CP, LOM …
- **Specifically Math web approach with CAS.** The most commonly used approach consists to integrate Computer Algebra Systems to proprietary web system so that the teacher can write and organize the execution of small algorithms to generate the mathematical part of the exercises, for ex. [Web+Cas]. In that circumstance, web techniques are used for pedagogical organisations and representations. The major inconvenient of that approach is that it does necessitate that the teacher willing to introduce new exercises or pattern of exercises must be familiar with programming languages used by CAS and Web platforms.
- **(Our) Teacher-friendly approach.** Our approach tries to avoid the burden of technology by giving teacher easy to use, intelligent and efficient tools to design exercises and pattern of exercises. For exercises, the Aplusix environment already contains an exercise editor. It will not be described here. For pattern of exercises, our work relies on the work already done in Aplusix to give a definition and a structure to the global object 'pattern of exercises' [BOU-05]. It leads to the previously described map of exercises with patterns of exercises. But these patterns were hidden and unreachable, teachers were asking for some control on it, so we have worked on the design of a user friendly interface for teachers. Two ideas have conducted our work. The first idea was to try to escape the programming language barrier: whether responses are given in some natural language or responses are to be selected from predefined list of items. The second idea is to provide the teacher with examples of instantiation of the pattern as soon as enough elements are defined (see right panel, figure 3). In fact, we try to give immediate non intrusive feedbacks and permit natural use, as in Aplusix for students.

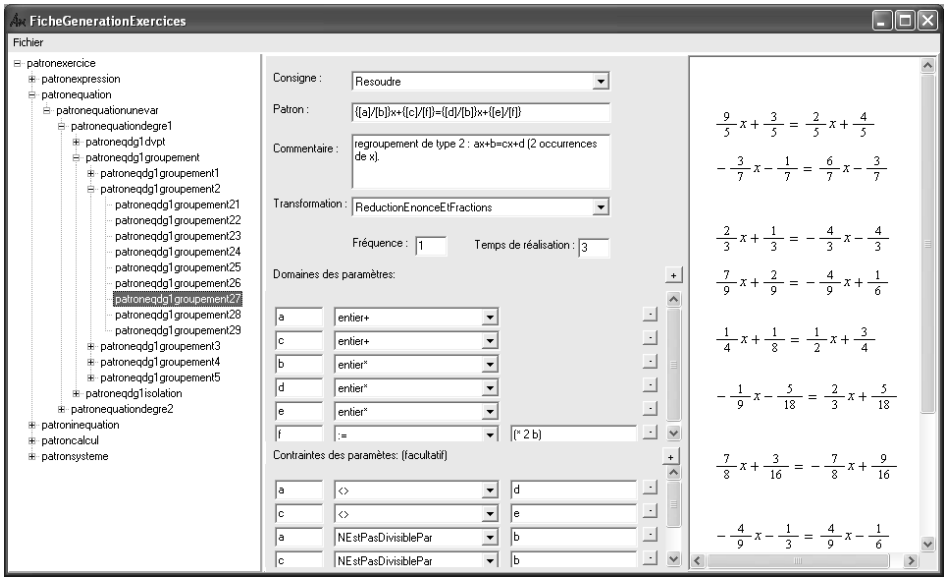

Figure 3: Editing patterns of exercises in Aplusix (prototype)

Conclusion

At the occasion of the design of a prototype for a pattern editor in Aplusix, we have studied, first the role and place given to teachers in TEL environments, second, the activities foreseen in TEL environments, and at the cross point, ways TEL environments propose to build exercises and patterns of exercises. From these studies, we have observed the influence of learning/teaching theory (behaviourism, constructivism, socio-constructivism…) According to us, such influence are due partly from the design of TEL environments and there are ways to liberated usages from it when TEL environments are been planned to cope with a lot of situations, and even permit free activities.

About the pattern editor, patterns of exercises were not new in Aplusix and generated exercises were appreciated by teachers, but patterns were unreachable and teachers asked for some control on it, so we have worked on a prototype of an editor. This is a first step toward an editor of pattern of exercise which could be integrated in the next version of Aplusix.

About generating exercises with random coefficients, two perspectives for the future can be imagined. The first one would be to try to extract the didactical variables used to define the hierarchy of patterns of exercises existing in the map of exercises of Aplusix, in order to build a new generator of exercises whose input would not be patterns but didactical variables. The second one would be to find a way to introduce didactics in the pedagogical construction imagine in the IMS-like standards.

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