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Analysing experimental design tasks in scientific labwork

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Context and general purpose

In the field of learning sciences by scientific inquiry process, most interest is given to the global process of scientific inquiry with reference to research processes, and to the exploration stage relying on questioning and building up hypothesis (Darley 1996; Séré 2002; Tiberghien et al 2001).

Our purpose is centred on the particular stage in which the experiment is being designed (Arce and Betancourt 1997). We state that this stage occupies a central position within the scientific inquiry process, as it requires the set up of the link between the stated problem and the experiment and its expected results. We assume that while designing an experiment, learners have to take charge of the stated problem and questions. Therefore it should improve the learners performances to interpret experimental results with regard to the initial scientific question. On the other hand, defining and organising tasks inside an experimental procedure, requires understanding why and how each task takes place in the procedure. Since this kind of scientific reasoning frequently involves scientific models, we assume that models and theory should take place in the process, and that the learners would have to relate them with the empirical elements (Bachelard 1979). Therefore we assume that the design of experiment could play an important role in the learning process of experimental sciences, since it allows learners to handle the whole process of scientific inquiry, and should help them to improve their performance in most stages of the process.

Research questions: analysing experimental procedures and design tasks in labwork

We are aiming to characterise the different aspects of experimental design, and address the question of experiment design as a learner's task that can be included in labwork activities. In this paper, we deal mainly with the question of the organisation of experimental procedures through the analysis of the usages in current labwork activities. The purpose is to identify and characterise these organisations, and build a model to account for some experimental design process, and try to relate this process with usual teaching situations.

This research derives from a previous project, Educaffix.net, which proposed a prototype of a computer-supported learning environment for a remote laboratory in chemistry (d'Ham et al, 2004). The learners' main task is to design the experiment, guided and validated by an artificial tutor.

Methods and Sample

In this first step, we analyse a set of labwork sheets in Chemistry, Physics, Biology and Earth Science, at last year high school and first year university level in France.

We set a research criteria table to analyse the labsheets. Most attention is paid to the experimental procedures and to the possible experiment design tasks that could be included. Among these criteria, many are set in order to identify and characterise the tasks belonging to the experimental procedure, and to map their organisation within the labsheet. We also try to follow and characterise the learners' activity around the experimental procedure. Interviews with the teachers have been used as a complement to this labsheets analysis, mainly to precise teaching situations.

We analyse and confront the procedures occurring in the labsheets with an a priori model of organisation. An iterative process is followed in order to adapt the initial model inherited from Educafix.net and lead to an improved model.

Initial model of experimental procedures

The initial model from Educafix.net sets a hierarchy within experimental tasks, with general tasks at method level and gestural tasks at the lowest level.

The complete task of experimental design is divided into "main stages" that define the general method to be used in order to solve the problem. The learners have to choose and organise elementary steps, named "actions", which correspond to general processes, and are re-usable technical procedures. The learner is in charge of thinking about, calculating and/or choosing the values of parameters corresponding to any chosen action. Specifying the parameters requires specific process knowledge that learners need to acquire. An organisation of tasks is standing underneath the computer-supported learning environment, each task being related to a specific knowledge (Chevallard 1985). It is shown that tasks can be structured hierarchically, and that there is no unique way of doing.

Improved model

Figure 1 shows the experimental design as a task tree, starting from the initial scientific or technical question to solve through the experiment. This kind of tree organisation refers to a downward analysis of a problem, well known in computer programming. As in the initial model we differentiate two types of particular tasks:

- In the higher level, tasks figured with an octagon correspond to the "main stages".
- Tasks on the lower level, figured with a square, correspond to "actions", elementary tasks as defined previously.

On the organisation point of view, the experimental procedure can be described as a sequence of tasks. In the following, we describe and compare four types of experimental procedure, and relate them to learning situations.

- The sequence of "actions", figured with the light grey line, correspond to an "efficient procedure for execution", meaning that it allows an efficient execution of the experiment. In Educafix.net, the experiment was performed by a distant robot, and this implies the existence of precisely defined elementary tasks. This procedure is not related to a learning situation.

- A complete experimental procedure that would be considered as efficient for learners having a given level of expertise, is figured by the light grey chequered line, "Efficient procedure for a student". It does not necessarily fit the previous "basic" procedure for execution (light grey line). The misfit areas correspond to tasks, as T2.3 for example, for which the detail of the experimental procedure does not need to be mentioned by/to the learners: these are "routinely" executed tasks, meaning that the execution has become automatic, with no need to think about (Chevallard, 1985).

- The black line models an experimental procedure that appears in a labsheet. We find that it often does not fit the "Efficient procedure for a student" (chequered line). These misfits suggest that the missing part relies on the student's activity. On one hand they can be related to the learners' knowledge of the experimental procedure: the learner can be supposed to know and remember, or to adapt or to create the missing procedure. On the teacher's side, the misfits can be related to the management of the learning situation: the missing part can be a real omission of the teacher and thus it is not managed; the teacher can also set that this part is relevant to the learners' knowledge; in a third case, the teacher has planned to manage this part during the class, and thus it does not appear in the labsheet. In the case of T2.1, the missing part is implicit, it can seem omitted and it is not managed in the labsheet. For the T1.2 or T1.3 examples, the spotted dark grey part of the tree figures a learner activity explicitly demanded in the labsheet. We think that a design experiment task should lay there.

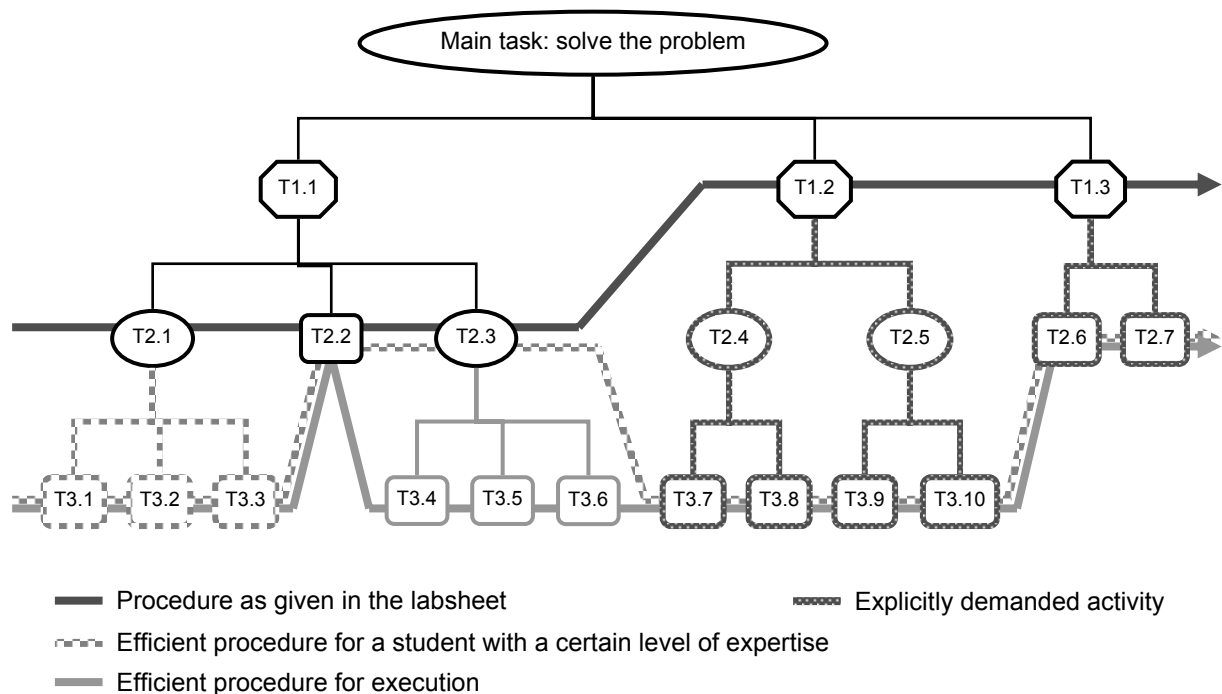


Figure 1: Plots of experimental procedures in an experimental tasks tree.

Conclusion and further implications

We analyse a set of lab sheets for currently used labworks in Chemistry, Physics, Biology and Earth Science. This leads us to build a model which is used to characterise experimental procedures and to analyse learning situations, considering the learners' activities to produce experimental procedures.

We aim to use such a model to map links between the learners' experimental design activities, the learning and technical objectives, the assistance to the students. Our purpose is to build and study learning situations that includes experimental design activities and that provides guidelines for learners.

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