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## To cite this version:

Patricia Marzin-Janvier, Cedric d'Ham, Eric Sanchez. How to scaffold the students to design experimental procedures? A situation experienced by 108 high-school students. ESERA 2007, 2007, Malmö, Sweden. pp.203. hal-00190036

**HAL Id: hal-00190036**

**https://telearn.hal.science/hal-00190036**

Submitted on 23 Nov 2007

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# How to scaffold the students to design experimental procedures?
# A proposition of a situation experienced by 108 high-schools students.

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## 1) Background, Aims and Framework,

Lots of works show that there is a lack of understanding by students in most experimental activities. For Hodson (1990) 'at the root of the problem is the unthinking use of the laboratory work'. For Millar (2004) there is an other problem linked with how students might interpret and explain data, facts, and relationships when they work in laboratories: for him ideas and explanations do not simply emerge from the data. Several other works show that the application of a so-called 'cookbook mode' in practical work is not efficient for constructing an understanding of knowledge by students (Tiberghien 2001).

This paper presents a proposition to improve the construction of concepts when doing experimental activities, and, in fact, to improve the construction of sense in experimental activities. We offer an opportunity for students to understand the nature of scientific work by understanding the complexity and ambiguity of empirical work and developing scientific reasoning (Committee on High School Laboratories 2006). To internalise the aim and the sense of the experiments, we propose that the students must write down the detailed experimental procedure they will follow subsequently, and thus won't apply a cookbook coming from an external point of view (Keys 1999, Hsieh 2005). The objective of our research is to propose conditions and guidance to make the student autonomous compared to the design of the experimental procedure, in order to design a situation with a minimum implication of the teacher (Brousseau 1989). The questions that we raised for analysing the situation are the following:

- How do students write their experimental procedures in comparison with the expert procedure?
- What sort of difficulties do they encounter?
- What kind of scaffolding can we propose to guide them for writing their experimental procedure?

We used task trees as a tool, to build situations and to analyse the student tasks, in reference to cognitive tasks analysis (CTA) (Clark 2006). The labwork situation is described 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. Our analysis of the student production looks up the experimental procedures of the students in comparison with the reference task tree.

## 2) Methods and Samples,

The experimentation was held during 2 school years, in 2005 and 2006. The sample is composed of 108 students in the terminal level of the upper secondary school (ISCED level 3A-17/18 years old), composed by 6 groups of 18 students, distributed in 6 trinomials of 3 students (36 trinomials in all). Each sequence holds out 90 min. All the student activities were recorded on audio and video numeric support.

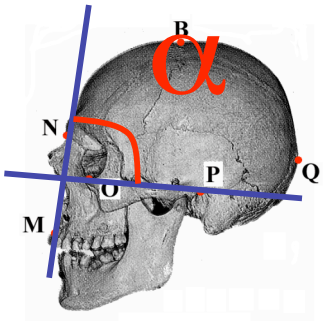


*Fig 1: measurement of a cranium's facial angle*

The concrete activity proposed to the students is a palaeontology experiment where they have to find a procedure in order to determine the facial angle of several homine crania. To solve this problem they have to choose 4 characteristic points on a cranium, and they have to project those points on a plan, to obtain 2 segments from which they can obtain the facial angle (Fig 1). This value depends on the prognathism of the cranium, which is an evolution indicator.

To do that, the students use a paper material that includes the description of the task to do and the problem to solve, some definitions (facial angle), the explanation of the measurement method and the work specifications. Students have the possibility to write a text, to complete the points on a cranium drawn beforehand or to write a free schema.

The expert procedure is composed by this ten tasks: (T1) identification of the measurement points on the cranium, (T2) choice of two couples of points, (T3) fix the slide on the wall of the aquarium, (T4) place the cranium in the aquarium, (T5) place a laser pointer perpendicularly with transparency, (T6) aim each point, (T7) mark the points on the transparency, (T8) remove the transparency, (T9) plot the straight lines, (T10) measure the angles with a protractor.

The experiment was held in three times:

A. In a first exploratory experiment (18 trinomials), we tested how the students write an experimental procedure. Students had to find and to control the totality of the ten tasks by themselves.

B. A new situation (12 trinomials) without the control of perpendicularity by the students: the teacher takes this task in charge and he/she controls it, because this task doesn't focus on the prognathism concept. We asked the students to write their measurement protocol and, in order to assess the quality of their protocol, to use the following criteria: (a) it leads to answer the scientific problem (*i.e.* evaluation of the prognathism – criteria of relevance) (b) it leads to obtain the same value of the facial angle for the same cranium (criteria of reproducibility) and (c) it can be used by another person (criteria of communicability). An additional criteria was used but not explicitly: (d) the protocol must be effective for measuring the diverse craniums of the sample (criteria of executability in the explored domain).

C. In a third step (6 trinomials), we added to the second situation a communication situation between students: they had to write down their experimental procedure for an other group of students who had to do the measurements according to the given procedure.

**3) Results,**

A. The first experiment showed that most of students managed to write an experimental procedure. Only two trinomials didn't. We have identified two main kinds of problems:

- Students had too much and too different tasks to lead, including the control of precision of the measurements, which is usually not devoted to them: for example they had difficulties to control the perpendicularity of the measurements (laser pointer, cranium position).
- Students had no possibility to think about criteria to choose the points on the cranium, and they had anything in the situation, which showed them if their results were relevant or not.

B- In this experiment, students focused their attention on the points' choice. They found pertinent criteria, but most of them didn't write any experimental procedure. They placed their points on the cranium drawing, but the majority of the trinomials (10/12) did not write

texts: they only described and justified the choice of the points, because they had not enough time to write them down.

C – In this last step, we introduced a real communication situation. All the trinomials have written an experimental procedure, corresponding to our attempts: the tasks are clearly formulated, communicable, and relevant compared to the initial problem. Several tasks have been written by all the students (T4, T5, T9). The first two tasks are mainly written on the drawing with legends. Several tasks are almost not written, because they are explained by the drawing figure (T1, T2), or because they are related to a too high level of details (T8). It appeared that the text is different if it is addressed to the teacher or to an other trinomial who has to follow the procedure.

## 4) Conclusions and Implications,

The proposition to make the students design an experimental procedure included:

- a knowledge analysis combined to a task analysis,
- an evaluation of the distance between the tasks to do and the knowledge to learn,
- a selection of the tasks that are devoted to the students, and those devoted to the teacher,
- an analysis to anticipate the difficulties that the students may encounter and a proposition of related feedbacks from the components of the environment,
- and the proposition of a communication situation.

This type of situation has been experimented in chemistry and in physics and it will be soon experimented with a concept of immunology (the antigen-antibody reaction).

Finally an Intelligent Learning Environment will be conceived, based in particularly on the conclusions of 'naturals' experimentations with students in biology, chemistry, geology and physics.

Acknowledgements:
We would like to thank the teachers who work with us: Daniel Devallois (lycée presentation de Marie) and Réjane Monod-Ansaldi (lycée Claude Bernard).
These studies were conduct within the CoPEX project, supported by the French ministry of education.

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