The Didactics of Science through Polymorphic Self-Made Experimental Apparatus of Quantitative Determinations. An alternative proposal for the teaching of Natural Sciences

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Abstract. *The undertaking of teachers' training in Natural Sciences is very difficult. This difficulty is related with the implementation of the two classic models "learn how you learn" and "active exploratory approach of knowledge" during the teacher training. That's because we have to use the same teaching style as we propose them to teach in their classrooms. During their basic and probably during the Academic studies, they have had the theoretical model of knowledge, as a unique model of learning Science. The disengagement from that requires a suitable model of teaching, through which the knowledge is approached experientially, within scientific – inquiring way. This model has the following advantages: a) it triggers their interest and the spontaneous attendance, b) they control the acquisition of knowledge, c) they acquire training and psychomotor skills and d) they collaborate. More generally, they are expected to behave as students with the same way as they are proposed to use as teachers in their classroom.*
Our laboratory has already a five-year experience in the application of self-made experimental apparatuses, for quantitative and semi-quantitative measurements. These two limits of precision, quantitative and semi-quantitative, coexist in most of the developed apparatuses. This co-existence constitutes an additional instructive approach through the concept of the Polymorphic Exercises in Science teaching [1].

Keywords. Polymorphic practice, Science teaching, Self/made apparatus.

1. Introduction

In our previous work (cf. reference [2]) we have analysed the concepts *"self-made construction"*, *"quantitative measurements"* and *"polymorphic exercises"*. As they constitute the main components of our proposed model the instructional and pedagogical framework, on which it is based, is explained thoroughly. During the last five years, we have acquired important experience from the implementation of our model during an in-service teachers training program, called *"Exomiosi"*. Through those teachers, we have had an experience of its application in their schools. Additionally we applied that model in our students' teaching of Science, through seminars and the teaching practice program, in which student-teachers of the Primary Education Department are participating. At the same time we extended the number of experimental apparatuses that we have developed and applied. We describe bellow the approach and the experience from their implementation, as well as their instructive evaluation.

2. Project method and stages

We apply a project method in all applications, with the following stages.

2.1 Sciences Area-Definition of the Educational Goals

Most of the natural laws, can give us ideas for an experimental apparatus, for quantitative measurements. At the same time, we can gather ideas from technological applications or from the technology of the ancient world. During the practice of a team of students, the emphasis is given on the planning of a set of applications. This set, constitutes a sample of approaches from various fields of Science. During student meetings, each one informs the team for his/her subject and his/her progress, so all students have an integrated idea of all projects. Our experience shows that, at the beginning there is a need, this team work to be supported by the teacher. In the following meetings, each student acquires a personal relation with his/her subject and

spontaneously seeks to inform the team about the work, the aims and the difficulties. It is characteristic that everybody understands the complications and all are making proposals towards an effective collaboration.

The subject of each project usually concerns something already processed from the teacher, (self-constructions ..-..). A processed proposal from the teacher however should not be repeated identically in each instructive period, but the student or the teacher, must seek for changes and exploitation of proposals taught. Additionally, a new idea affects the teacher's function, in the frame of research and experimentation. Subjects for self-constructions are based also on students' proposals according to their interests (constructions .. and ..). Both ways of subject choice have advantages and disadvantages. The advantage of a teacher's proposal is the clear objectives and prerequisites in an integrated entirety. The main disadvantage is that probably the idea is faced with decreased enthusiasm, compared to a proposal from the students themselves. The proposals from students are usually challenging and when they are adopted, they work with enthusiasm, regarding the whole process as a personal affair, without necessarily having comprehended the difficulties of the undertaking. In many cases, the disadvantage is that they cannot focus on the objectives and tend to exploit everything as far as the level of difficulty permits. They are either particularly easy or particularly difficult to implement their work for a given period of time. In every case the teacher tries, with the collaboration of students, to provide further dimensions in their proposals, so that they constitute a sufficient and completed objective. An additional effort is made so, that each construction can be graded in three different levels: for the primary school, for the High school/Lyceum, and for the University level (Polymorphic exercise), with corresponding objectives and requirements each time.

2.2 Initial Planning.

Study of natural law, theoretical calculations and bibliographic search.

In this stage the students are called to study in-depth the corresponding natural law, and search the literature. They do the essential theoretical calculations. The framework of the assignment and the expected problems are determined, and they study the theoretical divergences. The student writes a brief work-proposal with an initial plan for discussion and a likely timetable on the construction. This timetable and the plan usually have the value of a review. In this stage, the student works alone, with general directions from the teacher.

2.3 Final Planning.

During this stage the final planning of the apparatus is done, with the collaboration of the teacher. Critical points of the initial plan are pointed out and the students try to foresee possible adjustments for physical quantities that they cannot estimate accurately enough with their theoretical background. The aim is not to replace the initial provision, but to make as many corrections as needed, in order to make it functional and effective. For this reason there must be an anticipation of adjustments in critical points. Although in practice, the most likely thing to happen is the need for a new construction after the initial prototype, it is an important teaching tool during the study to estimate all the crucial points. This procedure helps in the understanding of the phenomena as well as in the final review of mistakes in a self-monitoring process of students.

2.4 Aesthetic requirements, materials

Particular emphasis is given in the aesthetics of the construction. The aesthetic requirements support the creativity and the growth of interest for the construction as the student faces an opportunity for a personal expression. At the same time it supports the development of skills in the use and handling of new materials and the practice in new methods and techniques of exploitation.

The materials that are used should be common, easy to be found in the market and as cheap as possible. The required mechanical equipment should not exceed the usual equipment of a school or a house. (Manufactures … require only an electric drill).

2.5 Construction

In the stage of construction we can identify the following:

a) Combat and abandon stereotypes specific different skills between men and women. It is proved in practice that students are capable to handle the same things, despite of being male or female. It has been

observed that in female students special skills emerge, which they realize for the first time and this causes an excitement to them.

b) Essential personal engagement of each student with his/her self-construction. The construction is not just an obligation for the course, but it becomes something worth to be dealing with, which is beautiful and functional. This makes the assignment a pleasant work. From now on there is no need to make plans and schedules for meetings, because students are interested in participating and they arrange things as necessary.

c) The teacher intervenes for proposing ideas and solutions. That supports the development of the construction and students improve their knowledge, on the application of theoretical data into practice and the use of materials.

2.6 Calibration, Measurements, Errors

After the completion of the construction, we have the calibration of the apparatus, following the procedure that already has been prefigured theoretically. Special interest is given in the comprehension of the concepts '*precision*' and '*resolution*' through the elements that consist the calibration procedure followed by repeated measurements, control of measurements, statistical analysis and localisation of errors. The analysis and processing of errors and the appropriate adjustments of the apparatus constitute henceforth the stage through which the students comprehend completely the natural law, in which the self-construction is based. We give a great emphasis on the error analysis. Independently of the size of the error, it is analysed in depth looking for ways to avoid or even minimize it. This search and analysis has to be done, independently if the error has a size acceptable to that apparatus. The treatment of errors will help in the complete comprehension of all parameters involved and how each one and all together influence the measurement.

2.7 Results of application

It is particularly satisfying for the students to build something that functions according to their expectations. This of course does not always happen. In the case where, despite the efforts, the apparatus does not function, they also feel satisfied with the course because of the analysis of stages and the justification of failure. Independent of the success or the failure, they feel capable of applying their knowledge, in studying, manufacturing and checking something out.

2.8 Writing of work

Students are writing up an essay of a small size, with the final construction, the problems that emerged, the way that were solved and a series of directives to someone else, how to repeat the project.

The experience of the application of the model showed, that the route followed between teacher and student, leads to an authentically active participation of students in an exploratory process during which proposals are emerged, processed, tested, rejected or are being accepted through peer collaboration. During this collaboration the teachers 'fatefully' banish their 'authority' and allow the handling of knowledge and his/her experience in an inquiring process, in which the student becomes participant straightforward. The experience of this type of research that the students acquire is useful and essential, for the activation of an inquiring interest of the students in the future.

3. References

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