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Editorial Quality of Science Education (IV)

Calidad de educación en ciencias (IV)

In our previous editorials we analyzed different methodological factors what directly influence the quality of students knowledge and skills (Orlik 2001). Methods of numerical problems solving (PS) is another important part of the science curriculum for the secondary school and university that can improve or lower the quality of the educational process especially in Physics, Chemistry and Mathematics.

It's known that the PS of numerical problems (NPs) is a difficult task for students of secondary (high) school and university. For many science teachers explaining the ways of PS of NPs in the class is a difficult task, too, and the methodology of resolution of the problems cannot be a task separated from other objectives of science teaching. It is a difficult matter, but it is connected in a systemic way to all other objectives and major subsystems of the curriculum.

There have been a lot of different papers about PS (Shatalov 1980; Harron 1996, De Jong 1991; Hayes 1889; Erigin, Shishkin 1989; Gabel, 1990; Gabel, Bunce 1994). but science teachers can not say that the correct and effective methodology has been elaborated yet (Lederman, Niess 2000). To analyse and to look for the best methods of explaining, it is necessary to take into account the typology of NPs in Physics, Chemistry and Mathematics. These problems can be of the basic level of difficulty or more complex (for example, of mixed types which require deep analysis and other high order cognitive skills). The most difficult of these NPs are Olympiad problems for secondary school and research problems of university level. Of course problems can be classified from different points of view; for example, taking into account the difficulty, as we mentioned before: **A.** Typical problems. They are generally the easiest problems of the course, for which it is necessary to use only one of the chemical concepts. **B**. Intermediate problems, whose solution requires only two basic concepts. Many of these problems come from different topics and students don't always have the algorithms to solve them. **C**. Difficult problems, which require the application of high level abilities and many concepts of different topics (Leenson 1998). There is a good classification of numerical problems on the basis of objectives, data and methods (Johnstone, Wood,.Sleet, 1993; Chittleborough 1995).

The PS is always a very complex psychological process that implies the understanding of the language expressing the problem, the interpretation of the data, and the understanding of the scientific concepts involved in the solution. In addition the student must have the ability to apply the necessary mathematical operations to look for the solution (Gabel, 1990; Gabel, Bunce 1994). For successful PS, it is very important for students to understand well the theoretical concepts of the topic, with the strong connections to the NPs of the current theme of the course.

Teaching practice shows that students have a lot of difficulties with mathematics because the solution of the NPs in the different courses presupposes the important requirement that the students should have previous knowledge and abilities in the respective topics of mathematics. Some students can not understand well which numerical data correspond to the main objectives in the given problem, and the correct relationships of these data with the important concepts. To help them, the teacher can apply an old recommendation for the classes of physics and chemistry: to make a visual emphasis of numerical data (Orlik 2001 b).

Many difficulties students have at the initial stage of PS involve understanding the problem : they do not understand the sense of common scientific and technical concepts (factor, relative, appreciated and others) or they don't understand the key concepts (mass, volume, temperature, molecular mass, molar mass, molar volume, density and other). To help students in this case, it is necessary to write the text of the problem with clear language and in positive rather than negative form; to use active and not passive voice to explain the sense of new concepts; to teach key concepts better; and to specify better links with the PS of the concepts studied in class in the theoretical part of the course (Gabel, 1990; Gabel, Bunce 1994).

According to the traditional methodology, many teachers explain the solution methods to the students in the following way. In class, the teacher shows the way (or algorithm) for solving a certain type of problem, mentioned on the previous pages, with 1-2 examples. The students also do the exercises later in class with 2-3 problems of this type, and then they receive the homework to solve some problems and to learn the resolution technique better. This procedure is repeated for each topic when they need to understand a new type of problem in the course. Many teachers suppose that this traditional methodology should give good results, but it is well known that many students don't achieve the necessary objectives in this way.

The technique involving the use of algorithms is common in the classes of Science in PS (Schrader 1987; Bodner 1987; Frank, Baker, Herron 1987). It is known that the algorithm is a series of rules to calculate something and this concept is being used a lot in the calculations involving computers. For example, the common conversion factors used in problems are algorithms too, and facilitate the conversion of the units of measures during the resolution of the problem (Loebel 1974). There are some procedures that help the students to build the algorithms what involve asking each student to write several ways in which he/she can solve the problem or having problems of several types, where the students can choose a certain type of algorithm for the solution, etc. (Kean, Middlecamp, Scott 1988)

One of the negative sides of this methodology is that the professors almost always represent the algorithm in oral form without the appropriate visualization of the steps of this algorithm. The representation of the process of PS plays an important role in achieving the aim of teaching (Hayes 1989; Bodner, Domin 2000; Wadding 1988; Phanstiel 1990). To improve the visual representation of the steps for the solution, schemas-algorithms (SAs) can be used (Orlik 1996, Orlik, Mikhailov, 2001). The SAs are types of schemas, and they can be used in the resolution of problems of the different types, described previously . The practice of using SAs in the classes of science subjects shows that this method helps the students to acquire good abilities for PS. But according to teaching experience and published papers, the algorithms work well in the resolution of typical (generic) problems, but it seems they can not give good results for more difficult problems.

The heuristic shows the general methods of the PS (Fridman, Turetsky 1989; De Jong 1996) and there are various heuristic guidelines to facilitate this task; for example, the analysis of the content of problems, short descriptions of the data, rewriting of the content when it is necessary. The division of a problem into 2-3 sub-problems can also facilitate the search for the solution.

For example, Polya's four steps are well known in PS (Polya 1945): 1. Understand the problem; 2. Write the plan of the solution; 3. Carry out the plan; 4. Analyze the plan on the way to the solution. Each one of these steps needs the professor's special effort to teach the student how to accomplish it. This should be carried out during the high school period, and not only in the classes of physics or chemistry but also, in mathematics to form general abilities to solve problems.

Some authors (De Jong 1996) recommend the heuristic focus for PS, based on the steps of Polya in the absence of the algorithms. Using this method, the students work in small groups. However the professors who it participated in this work liked both methods equally: the algorithmic and heuristic.

The change of structure of the problem – restructuring is also a good technique to facilitate the solution. For example, the experts in PS have the concepts arranged in a special net of concepts whose construction facilitates the work. The experts also spend a lot of time in planning a strategy for the resolution (we know that the beginners prefer to go toward the use of formulas or algorithms immediately, and this method doesn't give positive results). The heuristic methods are necessary in the solution of difficult NPs, and such problems are always the main task in the Olympiads in Physics and Chemistry.

It' s known that frequently, the teacher doesn't have enough time in class to solve the necessary number of problems, to permit the students to develop the necessary solving skills. Some teachers – innovators can handle this difficulty; for example, V.Shatalov (Ukraine) and his followers (Shatalov 1980). He generally starts the chemistry and physics classes in the traditional form, with PS where the teacher explains the algorithm of PS. The students repeat this algorithm, in some generic problems. But the homework can be formulated in a different way: "To solve all the problems of this type in the textbook and also in other books, in the special notebook for 1-2 weeks ". With this methodology the students help each other to improve the techniques of solution and the teacher constantly helps the students and is creating a special environment in the educational process, where each student not only has to but wants to fulfil this task and to learn PS better. Also different types of competitions to solve the problems are organized, up to the solution of some Olympiad problems. This methodology produces such remarkable results that practically ALL students of the group can obtain good solving skills in ALL types of necessary problems, with excellent or good grades in their exams.

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