Passion Research

A Joint Venture To Interest High School Students in Chemistry[1]

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Just before 1985, I had begun to wonder whether the "school" approach to experimental sciences was really suitable for its goal, making secondary school students aware of science, when the National Center for Scientific Research (CNRS) and the Department of Education created a joint venture called (by the CNRS) Passion-Research. Immediately I informed the CNRS of my interest. Madeleine Abouaf was searching for new ways for her physics-chemistry teaching and she contacted me. We began to work together for the school year 1985–86. The objective of Department of Education as well as of CNRS was to "make the students do scientific work with the help of a CNRS researcher". There was therefore great freedom of expression, which led to some original work but needed more imagination. I shall describe some basic ideas about Passion-Research and two practical projects done by the students on organic polymers and on color (*1*).

Some Basic Ideas

At first, the combined CNRS–Department of Education venture was defined as follows: a CNRS researcher is in charge of a high school class to give the students an opportunity to do some scientific work, even if it is not included in the Department of Education program. This involves the effective participation of teachers, students, and the researcher: teachers, to ensure good application to teaching; the researcher, to set a good scientific standard; and students, to be active participants. These are of equal importance for the harmonious functioning of Passion-Research. They led to three main consequences. First, a complex multidisciplinary approach and a wide range of practical work. Second, further training for some teachers by the researcher in the field of organic polymers. And third, the joint venture has evolved from practical work to a change in the teaching of chemistry, which was at first unexpected.

I want to describe briefly my concept of a multidisciplinary approach (*2*), which involves:

- The participation of nonscience teachers: French, history, foreign languages, etc. Aromas and perfumes and color were taken as one of topics for the examination in French (at the end of 11th grade).
- A wide range of topics to be studied: polymers (1985–89), pollution (1990–91), aromas and perfumes (1991–92), color (1992–94).
- The opening of the high school to the outside world: *their* researcher—*their* scientist! presents the topic to be considered, such as the study of pollution in Venice (Italy), the study of aromas in Grasse (France).
- The work was published: posters for the "Science Festival" *(Science en fête)*, a scientific paper in the *Bulletin de l'Union des Physiciens,* a poem about the polymerization of styrene.

Each topic offered something new in the approach to science: polymers, the "complete" approach of a true research project; pollution, a joint venture with another university (Paris VII) and study in a foreign country; color, a booklet written by the researcher to introduce the subject, which includes chapters on historical study, a literary point of view, scientific study—light, eye, dyes, and conclusions. Adhesives for wood was the first topic to involve a technical high school for wood *(lycée technique du bois)*.

I shall now describe in more detail the practical work in the case of organic polymers and mainly color.

Polymers

The first topic was organic polymers because it constitutes my main research. I wanted to make the students of lower sixth (11th grade) follow a "complete" approach to research in four steps. But is it possible in every case or only in a few (*4*)? The four steps were

1. documentation in various foreign languages to find the work to be carried out
2. practical work
3. a scientific discussion between the students and the researcher about the validity of experimental data
4. publication of the results

For this topic (1985–1989), these four steps were carried out in the course of the preparation and molecular weight determination of polystyrene and polyesters. A radical-type polymerization was used for styrene and polyesters were obtained by polycondensation of an acid–alcohol. The molecular weight determinations differed also. The special equipment to do these experiments was provided by the researcher's laboratory. The practical work was presented by the teacher during lectures.

Scientific Discussion of Data Validity

It was not possible to publish all of the experimental data, owing to their great dispersion. Some data should have to be discarded, but that could have been done only if all scientific arguments for this had been presented to the students. (For example, the reaction was not carried out at the chosen temperature; the polymer was not recovered completely; the starting time was uncertain, giving wrong durations.) This led to a notable discussion between the students and the researcher, because French teaching does not mention the concept of scientific doubt about the validity of experimental data. For students, the data obtained during practical work given by the teacher are necessarily good data! Then the data were published in the *Bulletin de l'Union des Physiciens* (*5*) and as a poem in *Science...on tourne!* (*6*).

Color

Synthesis of Dyes

Numerous colors were prepared:

1. *Azo-dyes*. This family was chosen because the tints are very diverse and the chemical compounds (aromatic amines and phenols) are not expensive;
2. *Indigo*. Condensation of 2-nitrobenzaldehyde with acetone in the presence of caustic soda;
3. *Aniline black*. Aniline black was synthesized, and chromatography of dyes and selective dyeing were studied.

Azo-Dyes

Diazotization. This reaction introduces the azo chromophore (the N=N group) by reacting an aromatic amine with sodium nitrite in acidic medium (HCl). Aniline (aminobenzene) was chosen for two reasons: it is not expensive, and the diazotation is complete within a few minutes even at 5 °C. The solutions were dilute enough to avoid risk of the diazonium salt exploding. Only 1/40 mol (2.2 mL) of aniline was used to obtain a mother solution of the diazonium salt, which was then coupled with solutions of equal molar quantities of phenol or aromatic amines. The reaction is:

$$2HCl + C_6H_5{-}NH_2 + Na^+ + NO_2^- \rightarrow C_6H_5{-}N{\equiv}\overset{+}{N}\overset{-}{Cl} + 2H_2O + Na^+ + Cl^-$$

Coupling. The following coupling reactions are involved:

$$C_6H_5{-}N{\equiv}\overset{+}{N}\overset{-}{Cl} + Ar{-}O^- + Na^+ \rightarrow C_6H_5{-}N{=}N{-}Ar{-}OH + Na^+ + Cl^- + 2H_2O$$

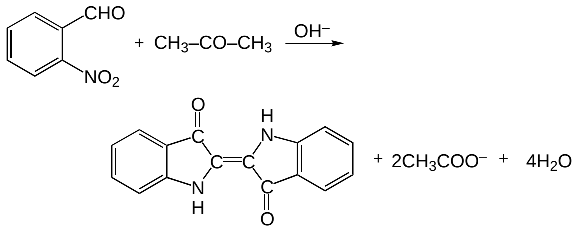
$$C_6H_5{-}N{\equiv}\overset{+}{N}\overset{-}{Cl} + Ar{-}NH_2 \rightarrow C_6H_5{-}N{=}N{-}Ar{-}NH_2$$

where Ar represents a complex aromatic formula that may carry substituents such as nitro, acid (COOH or SO_3H), aliphatic (CH_3 etc.), or halogen.

When 10 mL of the mother solution was added to the solutions of various phenols or aromatic amines, the color appeared immediately. If the dyes were not soluble in water, they were filtered off and dissolved in alcohol. Then little pieces of cloth were immersed in the solutions. They acquired various tints, which differed according to the nature of cloth! The difficulty in obtaining the same tints with the same basic reagents in equimolar quantities showed the students the importance of always having the same dye lot for their wool (to make a pullover) or for their wallpaper.

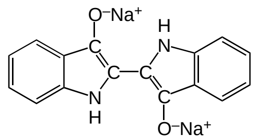
Indigo

The synthesis of this blue dye was carried out by condensation of acetone with 2-nitrobenzaldehyde according to the following equation:



indigo

Indigo precipitated immediately when 2M NaOH solution was added. The precipitate was washed with water until colorless to give an 80% yield. This compound is not soluble in water. Therefore to be used it had to be reduced by sodium dithionite to a soluble leuco derivative:



leuco derivative

A piece of cloth was immersed in the bath, washed with water, and oxidized by air to reveal the tint indigo. The blue tint varied according to the concentration of indigo in the leuco derivative solution.

Discussion

I succeeded in introducing some "colored" science in the humanities. I deduced this from the reactions of both nonscience teachers and students. A history teacher gave us a presentation about the colors in painting to show life in France at the end of the 19th century. The students wanted to know how the dyes were made in industry. A student presented "Ancient Ceramics and Its Coloration (Roman and Greek)". Another student contributed a cotton tee-shirt to be dyed with the indigo made by the students at the high school. I did this during a lecture.

For the color study, I had students whose studies emphasized literature (the L section of lower sixth [11th grade], who specialized in literature but also studied science), for whom a historical study and a literary point of view were new in a chemistry class and chemistry was not of great interest. I presented this topic as "introducing some science in the humanities" during a short conference, in which I told them that the point of view of Goethe and Newton about color was very controversial and that culture was something continuous and present in everything—French, chemistry, history, foreign languages, etc. The discussion that followed was very exciting. The questions of Goethe and Newton and the continuity of culture were highly provocative, since teaching is still separated into many different topics.

I tried to introduce the scientific process to high school students. The first idea was to make the students active participants. For this purpose, it was important to have them do a scientific project (i.e. practical work) with the help of a CNRS researcher. They saw that their work could be easily related to the work done by the researcher at the university. Then, they saw also that chemistry studied during lectures with a teacher could be applied directly in their scientific work: in the case of polyesters, the polymerization was an esterification and the determination of the molecular weight was an acid–base titration, and both techniques were studied with the teacher. The introduction of the concept of scientific doubt and of the continuity of culture was completely new. I tried also with the teacher to introduce a new concept: safety in chemical practical work. The evaluation of the hazards—styrene, strong acids, caustic soda, aromatic amines, risk of the diazonium salt to explode—was introduced before the work. Goggles, gloves, etc. were provided by the high school. We thus tried to give the students a very new approach to *chemistry, experimental science*. We hope that student attitude has improved.

Then, at the same high school, Camille Sée, we initiated (1994–96) "paper, its manufacture and the environment", for which I wrote a booklet (in French). I was asked by the Department of Research to try to introduce some science in a technical high school for wood in Paris. I began (1994–96) to study "adhesives for wood on the basis of synthetic resins: preparation and use, study of adhesion", for which I wrote a booklet (in French). So again I tried to "introduce some science in the humanities" and at the same time "introduce some science in the technical section"! Is all my quest for the communication of science directed towards nonspecialized people? I tried also to present "paper and the environment" in a primary class with the help of the teacher!

Summary

This joint venture, Passion-Research, between the Centre National de la Recherche Scientifique (CNRS)[3] and the Department of Education, was created to allow students to do practical scientific work with the help of a CNRS researcher. Through this joint venture, I tried to interest high school students in chemistry and to show them that there could be some relationship between their practical work and the work of a scientist. This approach could improve the students' attitude towards science, especially chemistry and experimental science.

Notes

1. Oral Communication presented at the ACS National Meeting, Chicago, IL, 19–24 August 1995.
2. Camille Sée High School specializes in the study of literature, foreign languages, and history.
3. Bureau of Scientific and Technical Information and Communication.

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