

# Teaching about Electron, Atoms and Molecules: How and Why

B. Danese<sup>1,2</sup>, F. Logiurato<sup>1</sup>, S. Defrancesco<sup>1</sup>, G. Gratton<sup>1</sup>, S. Oss<sup>1</sup>,  
R. Guardini<sup>3</sup>, R. Tarabelli<sup>3</sup>, N. Capra<sup>3</sup>

<sup>1</sup> *Università di Trento, Dipartimento di Fisica, Via Sommarive 14, 38050 Povo (Trento), Italy*

<sup>2</sup> *IPRASE, Via Gilli 3 (località Centochiavi), 38100 Trento, Italy*

<sup>3</sup> *Museo Tridentino di Scienze Naturali, Via Calepina 14, 38100 Trento, Italy*

## Abstract

*An activity that combines lecture and interactive laboratory about atomic physics for secondary school students has been set up by the Phys Dept in the context of the Museum, in Trento.*

*The method of teaching is based on three main pillars: personal time with hands-on objects (original molecular models, vibrating strings, spectroscopes), narration time (fundamental concepts, fun, experiments, remarks), and computer time (movies, music, interactive applets. Projected on a white blackboard).*

*The approach to the microscopic world (across the onionlike layers of matter) and its various means of description are presented.*

*The ideas and materials of this activity can be used in different contexts: in a comprehensive half-day in a dedicated room (as is currently going on), or split into many pieces with more detail and spread over the ordinary lectures in schools.*

*The activity reached its full blossoming thorough a close collaboration between researchers in physics education and senior educators.*

*Attention to facts, rigorous reasoning, primacy of objects, are the main reasons that make science education important. In addition to this, physics or exact science is at the root of every scientific discipline: chemistry, biology, geology... and therefore is a very important part of the culture of modern times.*

\* \* \*

## Introduction

LabCosFi (Physics Communication Lab) is a group of the Department of Physics, University of Trento. Its fields of activity embrace also teaching and learning. From teacher training to the development of objects, experiments, events for the classroom.

Here we present the hands-on lab “Electrons, Atoms and Molecules”. It is an activity dedicated to pupils. Mainly from middle-schools, but also beyond (age 11 – 14, and also 15 – 16).

The teaching of the basic concepts of modern physics - at different levels - has been discussed time and again. We think that it is important to keep in sight two basic points (to say nothing of the content). (i) pupils of different ages have their specific skills, attitudes and abilities, (ii) the didactic continuity.

The didactic continuity is a perspective where the third stage is reached after the second, and the second after the first. An example: phys or chem lab activities in high schools shouldn't be the first “experimental” activity that a student encounters in his school-life. These should be preceded by the performing of little experiments, and by the use of objects that improve hand-ability, at least from middle school, hopefully from primary school.

The continuous and slowly rising ramp of teaching is not incompatible with “spikes”. One of such spikes – with a lot of information about molecules, atoms, bonds, electrons, levels, waves – is the lab we have planned. We now present it, and discuss its “how” and “why”.

## How? The Three Paths

This “lab” has a duration of one morning and is hosted in the Museo Tridentino di Scienze Naturali. Classes arrive with their teacher(s) and find the educators and a dedicated room, with projection on the wall and objects on the tables already prepared. This activity alternate three different kinds of time, we may call them “the three paths”:

- personal time with hands-on objects and little experiments
- narration time
- computer time

### *(i) personal time with hands-on objects and little experiments*

There are moments devoted to hands-on activity. The first is construction of molecules, via original models “marble & springs”. These models consists of a marble representing the nucleus and springs representing bonding electrons. The important fact is that the covalent bond is obtained very simply with the superposition of the springs. The superposition represents the one between electron wavefunctions. This feature makes also very enjoyable the construction of molecules. Pupils, divided in couples, have a list of molecules to build, from the simpler to the more complex [Figure 1]. Many topics regarding molecules are thus introduced.



**Fig 1.** *personal activity: construction of molecules.*

In other moments “little experiments” take place. They are in some sense “pre-quantitative”, consisting in careful observation and description. One is with spectrosopes, observing the spectra of different lamps (mercury, sodium, helium). One is with hand-made monochords, observing closely the different modes of vibration of the string.

We found that “co-conduction” (two educators) is very well-suited for this kind of time. They may sit down with the pupils, to answer their questions, talk with them... with two educators it is possible to “satisfy” the whole class. Two educators may also work better in narrations and explanations.

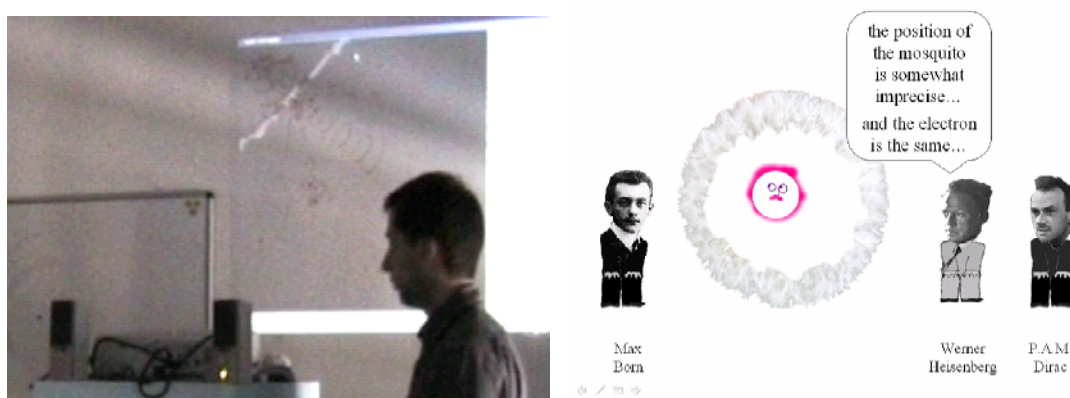
### *(ii) narration time*

There is a time to explain and to tell the story. The educators are rightly considered “experts” by pupils and by their teachers. They have the duty to focus on basic concepts, to explain them from many sides. Most importantly if it is the first time that these concepts are heard of. The concepts explained in the lab are “molecules are atoms bonded together”; trajectory vs wave behaviour; energy levels (connected with spectra); shapes of orbitals (connected with monochords).

The educator in some sense is a “good ole professor with chalk and blackboard”. He tells stories. One about the dapple-wing gnat, emphasizing the respective size of gnat, plasmodium, red cells, chlorochine. Or (interesting!) anecdotes about chemists and physicists. The educator also perform not-so-simple experiments with complicated-attractive objects (electron diffraction, ripple tank, harmonics) always clarifying their principles of operation. Pupils are called to take part in the experiments, and this helps to make a “learning atmosphere”. Pupils therefore can put forward their ideas, and discussions take place.

*(iii) computer time*

A good visualization of many concepts is achieved by means of the computer. It is irreplaceable with its simulations and applets about orbitals, waves, vibrating strings. We use it as it was a continuation of the blackboard. The projection takes place over a white blackboard, where it is possible to draw and write on. We draw trajectories, rays and wavefronts, orbits, and the discussion follows [Figure 2a]. It is also a way to overcome that sort of “diffidence” for the computer that some pupils entertain and that has to be taken into account.



**Fig 2.** a) computer and blackboard together. b) dialogue about mosquitoes and electrons.

We use the computer to underline important points, also with fancy dialogues between silhouettes of scientists [Figure 2b] or “concept cartoons” [1]. The De-Broglie Model of an atom becomes a stadium, where the nucleus is the ball and the electron is the Mexican wave circling around the tribunes.

With the aid of the computer we also add in the lecture sounds (of vibrating strings) and videos (about trajectories or the millimetre world).

**Why so?** (=why do you teach it this way?)

As shown, the method consists in the use of many different means to expose the content. We found that they can co-exist very well together.

All these means (objects, narration, computer...) constitute the background, from one side not directly connected with atoms, but from the other side very important for the communication. The introduction of the means for experiments and hand-ability is an answer to the specific needs of the pupils. But also, objects have their own magic in transmitting the content.

They help in the construction of an atmosphere for learning. This, of course, owes a lot to the educator, the teacher and the pupils. This atmosphere is a 0<sup>th</sup> step to be taken, it helps everyone. And it is also useful in develop listening and deepening of questions, hand-ability and personal

engagement. It makes it easier to take a breath, and pupils need it, even if sometimes it seems that they don't need it at all. It is because they have their own times.

### **Why?** (=why do you teach it at all?)

About the importance of these themes no one does discuss. But, as already said, to teach or not to teach the basic concepts of modern physics to pupils... that has been endlessly discussed. The two extreme positions are: "*NO you don't have to teach it, it's preposterous, at that age misconceptions are too strong, and they haven't enough preparation to grasp it properly*" and "*YES you must teach it! It's overall important and at the root of every scientific discipline. You shall not leave them in misconceptions and half-truths. You must teach it first*".

Our effort has been the underlying of a core of important topics, and its "translation" (with the means described above) for an audience of pupils. With enough rigor and completeness. These topics, as already said, are: molecules, atoms, bonding of atoms into molecules, fall of the concept of trajectory, travelling waves - electrons - diffraction, constrained waves - harmonics - levels - spectra.

While students of this age are every day bombed by the media with continuous and sometimes shallow references to atoms, DNA, etcetera, the contents of this lab aim to form a seed that pupils may feed and grow up in the course of their studies. In Italy the "systematic study" of physics is at age 17-19. Before, one has to plant the seeds of everything necessary for it.

The lab in a sense is a support for teachers. They may use it as an introduction as well as assessment. They can import and develop materials and ideas in their teaching. From this point of view, it is a concrete continuation of teacher training, an answer to upgrade the teaching in certain critical areas. We are working to diffuse more and more the materials and the ideas.

We think that a true scientific knowledge can be built from an early age. At that stage, it is made of marvel, observation, hands-on, discussion, curiosity, little experiments. Even if a deeper grasp of modern physics has to be left to more mature ages, pupils retain all the above-mentioned attitudes also when taught about electrons, atoms and molecules.

[1] Brenda Keogh, Stuart Naylor and Catherine Wilson, "Concept cartoons: a new perspective on physics education", *Physics Education* **33**, 4 (July 1998)