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A GRADUAL AND INTERDISCIPLINARY PROPOSAL FOR THE TEACHING OF ATOMIC STRUCTURE: REFLECTIONS ON CONCEPTUAL ISSUES

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ABSTRACT

The main purpose of this paper is to propose a path open, modular, based on the laboratory that helps to develop, through education, a proposal for teaching / learning for one of the most difficult conceptual issues for students of Italian schools: the Atomic structure.

Keywords: Atomic structure, teaching/learning, Inquiry Based Science Education (IBSE).

INTRODUCTION

As part of the conclusions of the European Council of the 12 of May 2009 on a strategic framework for European cooperation in education and training (ET 2020), appear to be four strategic objective [1]:

- To make sure that lifelong learning and mobility become a reality
- To improve education and training quality and effectiveness
- To promote equity, social cohesion and active citizenship
- To encourage creativity and innovation, including entrepreneurship, at all levels of education and training

In order to achieve these targets, indicators and benchmarks that help to follow the improvements, have been identified. They include basic general indicators and context indicators that produce greater accuracy. The indicators and benchmarks are based on eight main areas of intervention in the strategy "Education and Training 2010". These areas are the following ones [2]:

- improve equity in education and training;
- promoting efficiency in education and training;
- making education and lifelong learning a reality;
- key skills for young people;
- modernizing school education;
- modernizing education and training (the Copenhagen process);
- modernization of higher education (Bologna process);
- "employability".

It is clear that in this context, the European economic growth is based on the centrality of knowledge and thus on investment in school. Being aware of the importance that science has in this scenario, forces to reconsider the role that the "knowledge" has for the growth of a country as well as the "creativity" as an indispensable element for innovation. We must overcome the rigid boundary of materials and use the "***laboratoriality***" [3], as a "place" in which to develop "the ability of analysis, the right clue" and then be able to apply the appropriate strategy to meet or know how to solve a problem. Laboratoriality therefore as a place of observation but also as a technology one, of the active methodology that is able to open up to the reality and its "complexity", that respects the logic of opening up to the "critical thinking", which creates a network of learning through the metacognitive teaching, the "cooperative learning" and "peer learning", [4].

The idea of this process arises from the consideration that the laboratory does not have to be the site of the ritual repetition of standardized procedures, often conducted by the chair with prepared materials and instruments ("kit" laboratory) (teaching transmission-reproductive), but a methodology approach to phenomena and situations that promote the active participation and leadership of students, improving their capacity-logical interpretation, starting students on a learning path based on research as a way to learn on their own, [5]. The laboratory becomes a place where you specify the object on which it works, filling itself with tools (hardware and software) needed to achieve it and consequently an activated learning is set up because it is linked to the know-how, [6]. The methodology used by the teacher is based on learning through doing: a few knowledge theories to learn the core themes essentials and many laboratory activities that guide learners to produce reports on its activities.

Finally, the size of the laboratory allows synthesizing the different dimensions that build the learning process, as well as ensures consistency with the disciplines' educational dimension, integrating the different ways to exercise the skills and competencies [7]. The proposed training course aims to provide learners with the knowledge and skills based on the atomic structure, and that is because, it has been structured thinking of a vertical path.

ITINERARY PRESENTATION

The atomic structure and consequently the molecular structure belong to those contents of chemistry that are difficult to understand for most of the students. Speaking of atom, means taking care of microscopic objects that have chemical properties: thanks to Dalton, atoms acquired their rightful role within the scientific community giving birth to the discipline that now we call chemistry. This last one has developed the typical formalism of the discipline, which allows to describe molecules, their forms and their reactivity; understanding atoms can develop a theory of the matter structure, which can explain its properties and its transformations. Relying on the concept of "laboratoriality", we, as part of a Master funded by the Italian Ministry of Education, in "Professione Formatore in Didattica delle Scienze," felt the need to develop an educational path which can introduce the basic concepts, starting from the atomic structure, and the physically founded periodic properties of atoms, molecules and then move through a correct description of the chemical bond based on electronic interactions.

A path that arrives from the macroscopic to the microscopic, and returns from the macroscopic to the microscopic. A historical path essentially, because we believe it is correct that students should be aware of the difficulties and concerns faced by the scientists involved in this field of science, but focusing on the phenomena that have had the merit of introducing new and fundamental concepts for understanding the development of the atomic and molecular level. A path that allows offering students an adequate understanding of scientific concepts. Therefore, our intention is to propose a type of instruction that is able to:

- limit the themes and topics to face and to prefer deepening these issues, allowing the assimilation of experiences that would otherwise remain on the surface and leave no trace;

- ensure the organization in the internal structure of the disciplinary notions and interdisciplinary links to create a knowledge system, which can result, as conceptual and reticular;
- Create links with the experience outside school, because it is impossible to build new long lasting knowledge if not from the preexisting cognitive organization.

In general, coherent activities with the scientific method are intended to:

- observe the world around us, with attention to relate objects and parameters (grasp regularity, differences, changes in time and space);
- describe what is observed in ways that lead from the illustrated or verb forms the use of numerical language and in general mathematical-scientific;
- imagine and design the experiment, to test advanced interpretation hypotheses;
- perform experimental procedures with the use of tools and construction of measurement apparatuses;
- organize their whole way of thinking to distinguish facts from interpretations, build ordered and systematic knowledge, build hierarchies between the gained knowledge and enrich their conceptual framework;
- acquire and process specific disciplinary language.

At the light of all this, we need a conceptual reconstruction from the point of view of the disciplines that follows the milestones that have seen the birth of interpretative models to examine the conceptual difficulties and learning (see Figure 1). We have therefore identified an experiential path that is far from the path that comes out instead following the disciplines programming using atoms and molecules in the Italian school. An illustrative example for everybody is the path students take, studying chemistry and physics: chemists treat the principles of quantum mechanics in the first or second period, while physicists do that only in the last final year of high school path.

Among the major difficulties that hinder student learning of the atomic and molecular structure there is, for sure, the acquisition of models in which they have to distinguish the structural properties of the phenomenological properties. In other words, it becomes extremely difficult for students to distinguish the matter as such by the changes it may undergo. These difficulties reflect the lack of knowing how to keep the distance between the phenomenological macroscopic aspect and the microscopic one or that of the model.

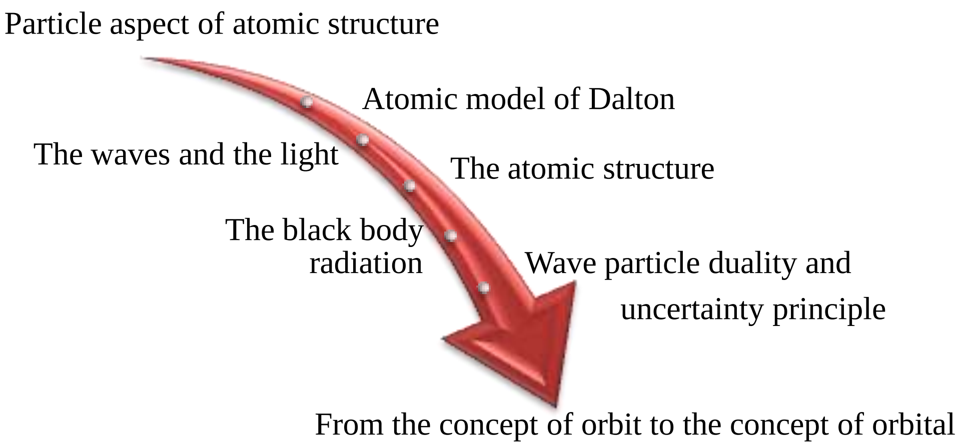

Figure. 1 Experiential path on atomic structure

To overcome these difficulties it is useful to start building a simple model in which we talk about particles and not about atoms or molecules. he term particle can describe the physical changes and you can process the model, living up to some axioms that can help you to understand the differences between macro (change of state) and micro (particles that retain the same mass, samples that do not change in the number and in the type of particles), particles which can be moved to and from.

The characteristics of the sample and its behavior allows you to define the concept of substance that applies to both the macroscopic and microscopic appearance. [8] The transition from the particle model to the one proposed by quantum physics forces us to understand the historical shift occurred before and after the advent of the new physics and the basic difference between classical physics (deterministic) and quantum physics (indeterministic).

The conceptual issues ranging loose, are regarding the origin of the Planck constant, the interference of light, the relationship between wave behavior and particle the introduction of the term quantization related to energy, the uncertainty principle, the transition from concept of orbit to the concept of orbital, [9]. In reference to the path on the atomic structure, the conceptual issues may generally be represented as follows:

1. **PART ZERO**: The first part of the educational work is based on consolidation / strengthening of a number of elements linked to concepts that are usually considered incorrect and / or distorted (misconceptions):
   - Entrance test
   - Mathematical consolidation
   - The electronic structure of the atom (state concept)

   The mathematical formalism is introduced in a gradual manner, but in parallel with the Quantum Mechanics (QM) “strong” concepts.

2. **CENTRAL PART**: In this context, it is appropriate to add some notes regarding innovative points:
   - " *If our world were to suddenly disappear, because destroyed by a cataclysm, the only concept with much information to pass on to posterity, argued, is this: all the objects are formed by atoms [or molecules], tiny particles that move in any direction, without stopping* ". (Richard Feynman).
     In the following proposal, learning is a common thread: the atomic- molecular matter theory.
   - The theory is divided, for the lower secondary school, in the following terms, interrelated:
     - There are gaps (the idea of vacuum) between the microscopic particles that are atoms and molecules, which are more or less close, but they meet only in mutual shock.
     - The atoms and molecules occupy a space, have mass and are in perpetual motion.
     - There are more than 100 different elements, described by the periodic table. Each species of atom, at the microscopic level, has two distinct properties: it has mass and capacity for combination with other atoms; it has, in short, mass and chemical characteristics but no other physical properties

(temperature, color, melting point, conductivity, etc.), typical of macroscopic objects.
  - The atoms can bind (in different proportions) to form molecules and crystalline solids.
  - The molecules have different characteristic properties, depending on the atoms of which are composed.

- The model of an atom proposed to the first two-year higher secondary school students is sufficient to explain most of the phenomena that are studied during this time, but later in the second two years and in the final one, a more complex model becomes necessary. The replacement of simpler models with more complex models should be for students a temporal progression of how the "vision" of the atom, has been developed in the course of time. The substitution of one model with another must be seen as a sort of "evolution" that allows us to understand how the particles are arranged inside the atomic structure, [10]

- How to introduce quantum mechanics with the laboratory? [11]:
  - Determination of Planck's constant
  - Young experiment or demonstration of light wave behavior
  - The experiment of Rutherford
  - Franck-Hertz experiment or the quantization of energy in atoms
  - The atomic spectra, light emission and fluorescence
  - Photoelectric effect or demonstrate the corpuscular behavior of light
  - De Broglie Wavelength
  - The uncertainty principle or the behavior of linearly polarized photons interacting with Polaroid, [12].

Didactical Path Strength Points:

- The QM typically ONLY "historic" approach is exceeded.
- The approach to the concepts mentioned above, is represented not in a systematic way (typical of Classical Mechanics), but in a more substantial one: it is based on the dual concepts of wave-particle.
- The workshop approach is related to what has been mentioned before.
- Notwithstanding the difficulties to enter such a path within an educational institution, which, although lacking in many parts, it is consolidated no matter what, it is logical to investigate the students' basic prior knowledge: mechanics, thermodynamics, electromagnetism and waves are the parts that most are taken into account.

3. **ENDING PART:** The end of the course is identified through means of evaluation: questionnaires, checks and repetition of the initial tests. The use of the IBSE methodology and its five steps is a perfect fit in the situation. One matter in particular seems to be clear in this context: there are some schools of thought that, while speaking about atomic models and especially about atomic structure, actually believe that it is appropriate to introduce the basic concepts of quantum mechanics and therefore all the difficulties that the introduction involved, in terms of teaching regarding the students’ comprehension.

For example, we do not agree on the fact that it is impossible to speak about orbitals, and therefore of QM, as part of a training course in the school of second degree where this is expected. This happens because, very often, it's possible to make a confusion between the concepts of orbit and orbital, as well as distorted concepts when talking about force fields are provided, in Physics, or when it comes to "corner" in Mathematics, but it is equally true that the problem will not be solved by returning it to a university course.

Very often, these concepts are related, incorrectly, to the one of "space region" which is about as far from reality. In this sense, it does not defect the one of atomic orbital, which is often presented as a region of space within which there is the probability of finding the electron. At this point, it is proper to ask: to avoid such confusion, should we no longer present the atomic structure according to the quantum mechanics version? Again: must we stop speaking of atomic modeling? This solution, in addition to being "*antididactical*", would also result not in line with the epistemological characters of scientific disciplines. It is well known that the concept of atomic orbital is one of the most difficult to deal with, as expected and requires basic skills of QM. In this context, it would be more appropriate to make a review of the teaching methodology of modern physics and chemistry, because the procedural defect, which is the basis of this difficulty, lies in the fact that a typically not deterministic study is faced with Classical Science determinism canons.

One of the first steps to make, in our opinion, is to have an adequate initial training of teachers, and in this sense it is legitimate to ask, if the agency delegated to the cultural education of future teachers, the university, does not have the its own responsibilities. Having said that, it is undeniable that an epistemological-historical approach is necessary: if it were not so we could no longer teach the atomic models, as affected by the same problem, appearing erroneous and distorted. However, it is necessary that students perceive as the whole history of science appears to be studded with errors and/or incorrect interpretations that have marked the way: from the magnetic properties of the matter studied by Ørsted coincidentally, the "Plum Pudding" Thomson model, to the Rutherford model, to Fermi studies on slow neutrons, and so on.

The use of the IBSE method [14], based on the discovery by students, can be one of the keys in order to solve these problems, then it is up to the teacher to collect observations more relevant for the understanding; this phase is so important because from its good organization derives the success of the whole learning process.
Only later students will be introduced to models, laws and theories, and only after that step, a correct vocabulary will be provided, which will allow them to explain in a scientifically rigorous way, the results of their arguments, stimulating independent research on the context studied.

On the other hand, what would the alternative be? Studying orbital and atomic models only after the first year of college? Frankly, it seems to us a paradoxical solution, not only because it would deprive the vast majority of students of the scientific knowledge necessary for a basic cultural education, but even because only a small portion of them would receive, in a not suitable age, an elite kind of training, very difficult to metabolize. The problem of scientific competence evaluation requires primarily a long reflection on science: in order to be meaningful, as well as essential (fundamental and generative), knowledge should be adapted to the cognitive structures and motivation of students. To develop appropriate assumptions of vertical curriculum in science area, disciplinary knowledge is undoubtedly a prerequisite.

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CONCLUSIONS

In this work an innovative curriculum path has been proposed, which allows students to acquire concepts, sometimes rather harsh and difficult, such as atoms and molecules, switching from the macroscopic worldview to the microscopic one and vice versa easily, acquiring important skills for the rest of their studies.

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REFERENCES

1. http://europa.eu/legislation_summaries/education_training_youth/general_framework/ef0016_it.htm
2. http://europa.eu/legislation_summaries/education_training_youth/general_framework/c11099_it.htm
3. Experimenta, Pensare e fare Scienza, documento prodotto dal Comitato per lo sviluppo della Cultura Scientifica e tecnologica, available on http://www.indire.it/lucabas/lkmw_file/licei2010/EXPERIMENTA.pdf
4. http://ec.europa.eu/youth/policy/implementation/peer_learning_en.htm
5. Frabboni F., La Scuola dei perché, available on kidslink.bo.cnr.it/irrsaeer/labform/relfrabboni.doc
6. Baldacci M., Il Laboratorio come strategia didattica, available on http://www.unich.it/~sasso/Baldacci_Laboratorio.pdf
7. Amben M., La dimensione Laboratoriale, 2006, available on: http://www.memorbalia.it/leonardo/pisa/perpisa2007laboratoiale.pdf
8. Roletto E., I modelli particellari nell'insegnamento, 2006, available on http://www.treccani.it/scuola/lezioni/in_aula/fisica/modelli/3.html
9. Stefanel A., La meccanica quantistica nella scuola secondaria di secondo grado, 2007, available on http://www.treccani.it/scuola/tesine/meccanica_quantistica/3.html
10. D Warren, Chemists in a social and historical context: The atom detectives., pag. 3. Royal Society of Chemistry, 2001 available on: http://www.rsc.org/learn-chemistry/resource/res00001332/the-atom-detectives
11. Fabri E., Introduzione alla fisica quantistica. Prima parte: i fatti,1999. available on: http://www.sagredo.eu/fq/fq21p1.pdf
12. Michelini M., Proposte didattiche per una fisica moderna, 2010. available on: http://www.fisica.uniud.it/URDF/laurea/materiali/pdf/proposte_didattiche.pdf
13. Mirone P., The orbital are really needed in teaching of basic chemicals?, 2003, CnS, available on https://www.soc.chim.it/sites/default/files/cns/pdf/2003-4.pdf
14. Checchetti A. & Fantini A., Experimental Determination of Planck's constant using Light Emitting Diodes (LEDs) and Photoelectric Effect. World Journal of Chemical Education. 2015, 3(4), 86-90.