AN ONLINE COURSE FOR SECONDARY SCHOOL TEACHERS

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Abstract
This study is about a course on Quantum Physics of the IDIFO Master, that is a blended II level Master for in-service Teachers' formation on Modern Physics and Problem Solving realized by 15 Italian Research Unit in Physics Education leaded by Udine. Data we took stress the importance of some characteristics of the course such as the study of different approaches (based on the results of university research activity) and the great number of collective discussions between teachers and trainers in promoting better results in constructing personal paths for the school.

1. Introduction
In order to realize adequate Secondary School Teachers' Physics training courses it is necessary to be aware of Teachers' previous knowledge concerning basic concepts of Physics and to pay attention to many crucial points, some of them coming from the fact that school Teachers are adults, so we have to deal with the problem of adult education and therefore the necessity of introducing particular educational methodologies, in order to reach some goals:

- to improve Teachers' knowledge of Physics;
- to improve Teachers' ability of referring to precise Physic theories in their pedagogical explanations;
- to improve the capacity of performing good laboratory activities and reports; as well as the ability in the use of computer.

The work we carried out is based on the comparison of two different Teachers' training courses. Both courses were centred on Quantum Physics. it is well known that secondary school Teachers have many misconception about basic notions of Quantum Physics (Petri 1998), (Kalmus 1992), (Wilson 1992), (Cavallini 1998).
In spite of their different contests (see section 2), the "background" of the students-teachers was homogeneous from the point of view of their previous university experience and of their teaching activity in Secondary School. The results of our analysis show the important role in improving Teachers' knowledge and didactic skills played by two main "ingredients": the contents (a lot of educational and didactical material, studied and created by different Physics Educational Research groups, was available) and the use of a strongly interactive and technological supported methodology.

2. Contexts

2.1 The "SSIS course"
One of the two courses [1]: "Quantum Physic Education and Didactical Lab", was held in Milan, part of the two years postgraduate Lombard SSIS (Inter-University Lombard School of Specialization for Secondary School Teaching)
Students attending "SSIS" (Vegni 2005) obtained, after a final examination, the "abilitazione all'insegnamento", i. e. the official qualification to teach a particular set of subjects in Secondary Italian Schools. The course "Quantum Physic Education and Didactical Lab belonged to the "Indirizzo" of scientific subjects: Computer, Physics, Science and Mathematics; it led to the qualification ("Abilitazione") which is a title that allows to teach Physics in the Italian Secondary Schools.
The course was attended by a group of 31 Students-Teachers; all of them were graduated in Mathematics (~ 60%), Physics (~ 20%), and Engineering (~ 1/5); they had been teaching Maths and/or Physics for more than two years and, at SSIS, they all had already attended the courses: Structure of Matter (20 h); Nuclear Physics (20 h); Quantum Mechanics (40 h); Particle Physics (12 h); Computer Methods for Physics (24 h).

[1] We'll call it the SILSIS course.

2.2 The "Master IDIFO" course

The course "Field Theory and Didactical Proposals in Quantum Physics" was a on-line-course of the IDIFO Master, that, as we have already said, was a National II level Master (Post Master degree) on Didactic Innovation and Orientation, centred on Teaching/Learning Physics and on Problem Solving for Teachers' formation. It was planned and carried out by 15 Italian Physics Education Research Unit in 2006-2008 and headed by the Udine research Unit. It was a blended Master with on-line courses and in-presence workshops. Nearly 50 Teachers entered the school (as students) after passing a selective initial examination and 22 of them actively attended "our" course. All of them were graduated in Math, Physics or Engineering; all of them had previous teaching experience. Before our course they all had attended the following courses of the Master: Special Relativity (20 h), Taylor and Wheeler way to Special Relativity (15 h), Quantum Mechanics and the Dirac formalism (10 h), Problem Solving for Orientation (10 h), Feynman's way to Quantum Mechanics. (20 h), The crisis of Classical Physics and the birth of Modern Physics (an historical approach to the conceptual knots of Quantum Mechanics) (20 h), Use of e-learning platform (10 h). For each course there was a forum in which everybody could discuss about the module content and ask for explanations; at the end of each module there were questions put to the Students in order to suggest a key to read the content.

2.3 Courses' programs

The program of both, SSIS and IDIFO, courses were the same and included:

- Historical introduction
- Phenomenology of free propagation of waves in continua fields. Wave eq. for "classical" matter beams
- Introduction to Quantum concept and to some Quantum Field Theory ideas
- A semi quantitative approach to the Structure of Matter
- Typical Misconception of High School Students

Both courses lasted 20 ours and, at the end, Students-Teachers were required to plan a teaching project for Secondary school students, based on one (or some) particular aspect (aspects) of the course. As mentioned above, there was a significant difference between the two situations ("SSIS course" and "Master IDIFO" course): the "Master IDIFO" course was an on-line course strongly interactive.

3. The research question and method

The research point at issue was: in order to develop adequate skills for Quantum Physics Teachers' Education, what are the influences of the methodology, of the contents, of the use of new technology in the effectiveness of teachers' training?

At the beginning, our work took into consideration the results of a ten years long research made on Students-Teachers of the course "Quantum Physic Education and Didactical Lab" held in Milan, (the "SSIS course") in which we studied Teachers' pedagogical ideas about light, atoms and Quantum "objects. We investigated the way Teachers deal with these topics with their Secondary School Students and which is the role played by Quantum Theory in their descriptions. During the course (which was repeated 9 times in the last decade, for more or less 30 teachers each time) we studied the initial conception and the development of Teacher's ideas about Quantum Physics and its Teaching contents and methods.

In order to make ourselves acquainted with Teachers' previous pedagogical concepts about Quantum Physics, a questionnaire has been given to Students-Teachers at the beginning of the course. It consisted of 10 questions that were really asked by Secondary School Students during School time and that we gathered in other previous experimentations. We asked the Teachers to answer the questions as they would have answered their own Students, taking care "of giving a real meaning to the answer, or a sense for Students" (they could be qualitative and/or quantitative; they could use formulas and/or drawings and/or metaphors).We wanted to know the role played by Quantum Theory in teachers' ideas and explanations.

The questions can be divided into four groups, according to their content: 3 questions were about light, 3 about the atom and its structure, 1 about the limits of the theories and 3 about the features of Quantum Objects.

Q1 "Prof., you spoke about light as a wave, then you spoke of photons, then you told us about dualism. But, at the end, what is really light?"

Q2 "… From double slit experiment we concluded that we cannot speak of photons' trajectories, yet when I perform the experiment, light gets out from the laser and comes into the photographic plate in precise points, but then what do the photons, that get out from the laser and come to the plate, do?"

Q3 "What is the photon?"

Q4 "You told us that Thompson won Nobel price ...: but even I were able to make such a model … a plum-cake with raisin, and besides, it does not even work!"

Q5 "Could you explain why energy levels in atoms are quantised?"

Q6 "Well, we saw a lot of atom's models… but you, how do you picture it to yourself?"

Q7 "… you told us about limits of validity of a theory… here it's the same: for classical experiments we use wave theory, for the black body and the photoelectric effect we use photons…"

Q8 "At the end De Broglie said that electrons, as well as photons, move in sinusoidal motion, or do they not?

Q9 "But if the electron has not a trajectory, how can it spin about itself?"

Q10 "Summarizing: the electron is in a well definite point with its velocity but, if we want to see it, we give it a kick that knocks it off from where it was… It does not look so important to me this Uncertainty Principle…"

4. Data analysis

As a result of this previous analysis, we can say that, the initial ideas of our Teachers, with minor differences, were all "distributed" in the same manner each year and that this distribution remained nearly unchanged year after year (see section 4) and we assume that the distribution of the answers to the initial test of the SSIS Student-Teachers be a good representation even of the initial pedagogical concepts held by the group of the IDIFO Student-Teachers. Here we report the data most recently collected in the SSIS course.

As a first criteria of cataloguing we tried to see whether Teachers "made use of" or "referred to" a complete Physics Theory (Cavallini 2008) or whether their explanations were made in terms of "common sense argumentations" or in a mixture of semi classical-common sense and/or semi technical words.

For what concerns questions about atom (Q4 – Q6) 40% of the answers were axiomatic and/or not argued; 45% were based on historical models, 15% were based on experimental evidences.

Here some examples concerning question Q5.

"There is a well established theory, called Quantum Mechanics, that is very difficult to understand at High School, but... that explains...". "Discrete atomic spectra clearly indicates that energy levels are quantized...". Differently from Classical Mechanic electrons in atoms can describe only certain trajectories, as Bohr model says...". "The emission of a photon of a precise energy in Bohr's model seems to me a good way to understand..."

- Other ideas on quantum phenomena (probably coming from the previous courses) emerge in a lot of answers as well, concerning:
- the quantum wave describing the state of the electron
- the probability of localising the electron (as a quantum object) that replaces the concept of its "contemporary definite" position and movement.

Here other examples of answers:

"Electrons are described by waves of probability that tell us where they can be found and as they cannot be found in every position around the nucleus they have only certain energies"

"Either electrons have define energy or they have definite position; and as we know that in an atom their energy is fixed than their position is uncertain and so we get orbitals"

But these new ideas coexist with the classical ones generating a sort of naives, confused, incoherent and even paradoxical answers.

- nobody referred to Quantum Field Theory (in answers Q4 – Q6), 40% were axiomatic and 45% could only speak about some experimental evidences.
- for what concerns question about Heisenberg relations, 21% of the answers were confused, 79% were wrong or schematic and not argued.

5. IDIFO Student-Teachers results

The course was characterized by a great amount of comments and discussion in the forum with more than 300 e-mails, 3250 readings and more than 100 documents with the homework of the students. This "shared" work put in great evidence both personal participations of Student-Teachers and their involvement. From the forum we can analyse the development of Teachers ideas both from a disciplinary, cultural and a didactic point of view; besides most of the Students prepared and experimented in their classes didactical paths based on IDIFO courses and also discussed their final thesis on these arguments. Moreover we have also the answers to the question put at the end of each module and to the final test that was equal to the initial test of the SSIS course.

To have a glimpse of what we believe was a success we report here some significant results concerning this test (to be compared to the answers analysed in section 4).

- For what concerns the questions about light (Q1-Q3), 47% of the students gave answers referring to light -matter interaction, 48% of them answered referring to Quantum Field Theory
- 90% of the answers to question Q4 – Q6 (about atom) referred to Quantum Field Theory (for examples "... electrons are described by waves... in an atom these waves are confined because electrons are negatively charged while nucleus is positive. So in an atoms these waves are stationary waves therefore they have a precise wavelength and this... via De Broglie... means that electrons have a definite momentum and energy"."In an atom one has a confined electron field and you know that when a field is confined its perturbations are harmonic waves...").
- For what concerns question about Heisenberg relations, only 5% of the answers were confused, 95% being correct.

As everyone can see, most Student-Teachers reached a more than acceptable reconstruction of their previous knowledge, and this is fundamentally ascribed to the complex structure of the master IDIFO (a more deep and complete study is still in progress and we'll give more details in a later paper).

First of all the fact the courses were on-line (as IDIFO was an e-learning project) forced Students to write their questions instead of speaking. This brought them to clarify first to themselves and then to everybody what they were asking, thus giving a deeper insight into their problems.

Second, there has been a long peer to peer debate among Students sharing their difficulties at very different levels: on basic Physics, on cultural development, on class situation and so on…

Third, the necessity of constructing personal paths to be tested in classes forced them to translate thematic knowledge and pedagogical content knowledge into concrete didactical sequences.

Fourth, the presence in IDIFO of many courses on Quantum Physics with many different approaches (one based on superposition principle and on the formalism of Quantum Mechanics, one on the logical-historical reconstruction of the main themes that brought to Quantum theory, one on the Feynman rules to QED, one on the different statistics underlying Quantum theory and one (ours) referring to Quantum field theory) greatly enlarged the Teachers' point of view, moreover the possibility of creating links among the approaches greatly stimulated and really opened their minds.

Fifth, the realisation of many experiments in two weeks of in-presence courses both as Students and as Teachers with selected High School Students, put a solid ground some of the "classical" Modern Physics experiments everybody has read of on paper.

Conclusions

We can say that the use of computer has greatly changed the dynamic of teaching/learning process in teachers' training courses from different points of view. At a first level of analysis we can say that on line forums allowed numerous discussions among students-teachers themselves and between teachers and university researchers. Speeches and debates, questions and answers, reflections, observations, concerning Physics could be done "among the Master Community all over the Italy" in real time, exchanging teaching experiences and research' results. The use of computer simulation played an important role in modelling (for examples the ones concerning Quantum Statistical Mechanics, Quantum Electrodynamics or Optics) Computer allowed the "vision" of real experiments whenever you needed (videos concerning the Modern Physics'

experiments were available on line). And last but not least all teaching material was always on the web.
The above mentioned methods and materials heavily influenced the obtained results which lead us to believe that a key point in teachers' formation is to give a "general frame into which different pictures learned in University courses can be linked" (Vicentini 2007), so that a cultural change may promote didactical innovations
More specifically in the case of the Master IDIFO three factors seem to have been very important.
1) The possibility of rethinking, with different approaches and "interpretations grids" and with computer based modelling activities, about fundamental Quantum Physics content (Fisher 2005). This point has been clearly stressed by many student-teachers.
2) The possibility of rethinking Physics for Teaching in the context of Physics Education research and its results (Duit 2005).
3) The possibility of a great engagement and involvement in debates and on-line peer to peer discussion that has greatly favoured meta-level reflections. In fact many e-mails refers to peer discussion while many home-work have been performed in groups.

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