



Focus on: e-Learning: requirement of the disciplines

E-learning in teacher professional development in innovation and formative guidance on modern physics: the case of IDIFO Master's Programs

Marisa Michelini, Lorenzo Santi, Alberto Stefanel

Research Group in Physics Education, University of Udine

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The professional development of in-service teachers is becoming an increasingly "hot" research topic internationally. Innovations in both methodologies and content are a challenge for schools wishing to respond to the demands of the knowledge society.

The second level biannual IDIFO Master's Program, offered as project of the national plane for scientific degree (Piano Nazionale Lauree Scientifiche-PLS) by the Research Group in Physics Education of the University of Udine, in collaboration with 20 other Italian universities, provides teacher formation in modern physics and formative guidance to in-service teachers in Italian high schools and is now being run for the fourth time. Based on research into the teaching and learning of physics, it started in 2006 was activated in e-learning every second year. The course is wide-ranging (it is worth 165 CTS) and allows for customized study paths to suit the needs of individual participants, both regarding content and length of study period: single

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modules (worth 3 CTS) and an annual Specialization Course (15 CTS) are run alongside the Master's. The organization of the e-learning formation, carried out using uPortal, is as follows: analysis of physics education research materials; web-forum discussions of content and methods; the compiling of teaching materials, both collaboratively and in personal project work; doing experimentations (teaching intervention modules) in high school students, analyzing and discussing online with peers and with professors-tutors- experts. The program has undergone continual revisions - based on feedback and reflection on the overall outcomes of the formation - while retaining its original structure. Analysis of project work and of the dissertations presented in the final exams has demonstrated the contribution of e-learning formation to capacity building through: access to research material and proposals; peer debate; a critical review of traditional approaches. The flexibility of the formative model is a key element for its implementation nationally in a wide variety of situations. The commitment required of the participants, particularly in the first two versions of the program, while resulting in an excellent preparation, also prompted the course designers to create more flexible study paths in order to allow participants to complete their training in a number of stages following coherent pathways. The educational research on the Master's is not just a source of materials and training content, but also a context for what concern teacher formation. The analysis of participants' learning processes in each module - like that on quantum mechanics - revealed both the characteristics of an effective educational innovation formative model, and the part played by peer interaction on web-forums in building participants' integrated expertise both regarding content (CK) and its teaching/learning (PCK). An analysis of the school experiment written reports high-lighted the role of the Master formative path in the didactic design.

1 Introduction

The teaching/learning of modern physics in high schools is still a subject of debate, although it is included in the curricula of most OECD countries (WebCern, 2001). In the ample literature covering proposals and study paths there is no agreement on either the subject matter or the approaches, or on the learning outcomes towards which to aim (Styer, 1996; Zollmann, 1999; Stefanel, 2008). The few teachers who include aspects of modern physics in their own programs do not therefore know where to turn and often end up following simplified, and not always consistent, versions of university courses. Most teachers also express a lack of confidence in this subject area, of which they are often not fully abreast, as a lack of sufficient formation in the subject area may be accompanied by other failings, not expressed, of the active strategies and in teaching/learning opportunities offered by laboratory and ITC (Olsen, 2002; Psillos & Niedderer, 2002; Michelini, 2003; 2004; Michelini *et al.*, 2004; Pospiech *et al.*, 2008).

A number of studies have demonstrated the need to build operative capacity, which integrates knowledge of specific subject areas with the expertise to overcome students' learning difficulties: that knowledge which Shulman calls Pedagogical Content Knowledge (PCK) (Shulman, 1986; Appleton, 2006).

The fact that teachers usually focus considerable attention on preparatory

explanations of classical physics which are as broad as possible means that it is necessary to look again at concepts and interpretations when dealing with the themes of modern physics; the resulting approaches have been shown to be ineffective by educational research (Zollmann, 1999; Olsen, 2002; Michelini *et al.*, 2004; Stefanel, 2008; Pospiech *et al.*, 2008). A reflection on the key theoretical concepts would therefore seem to be a necessary part of teacher formation, as is a reconstruction of the interpretative framework of phenomenology and a debate on the various approaches to teaching / learning proposals. Multimedia resources, particularly those of e-learning, are indispensable for the achievement of these aims, for the personalizing of the processes of rethinking concepts and reflecting on asynchronous modalities and for collaborative learning aimed at the sharing of a single conceptual framework and at didactic design. These tasks can be carried out effectively through increasing the value of basic e-learning tools like web-forums and the programs designed for collaborative writing (Warschauer, 1995; Rivoltella, 2003; Ranieri, 2005). Online activity, and particularly the collaborative drawing up of teaching/learning proposals, the efficacy of which for the development of cooperative skills, group communication, the control and management of one's own learning path, and time management (Warschauer, 1995), has now been documented, responds to the advice on teacher formation that emerges from research into PCK, regarding the design – and redesigning – of teaching materials in the scientific field.

Nonverbal communication and the lack of immediate feedback (Rivoltella, 2003; Ranieri, 2005) become, in this case, resources in the distance-formation of teachers, as long as effective tutoring is focused on a careful reflection and re-thinking of the scientific concepts involved (Angell, 2011) and a clear reconstruction in educational perspective, according to Duit's MER (2008) and b) the professional reformulation of didactic design (Bryan 2011), possibly adopting a blended modality (Warschauer, 1995; Ranieri, 2005; Yucel, 2006).

The multimedia and interactive nature of e-learning facilitates the necessary integration of the three teacher formation models: 1) meta-cultural, based on critical discussion of teaching/learning proposals; 2) experiential, involving teachers in an exploration of the proposal and of the didactic material to be used in class; 3) situated, with the integration, discussion and socialization of innovative projects implemented/experimented in the classroom. Tools like online forums contribute at the meta-cultural stage, in the in-depth analysis and sharing of source materials. The analysis of critical points in the subject content and of innovative teaching/learning proposals for modern physics, conducted by student peers, experts and tutors together, with their different perspectives and expertise, finds an effective platform in online networking which allows the integration of a reformulation focused on the enhancing of expertise in both subject content and methodology/pedagogy. In the experiential and situated sta-

ges, problems encountered in the preparation and carrying out of implemented didactic path in class can be shared online, rather than in face to face meetings; this flexibility saves time and increases the number of potential contacts, and makes peer-planning and action research possible in the redesigning of new study paths (Anderson, 2005; Glava & Glava 2010). Web-based tools are ideal for dealing with the necessary overabundance of available resources for research validated simulations (www.compadre.org).

The framework outlined above was the foundation for the designing of the IDIFO Master's (Battaglia *et al.*, 2011) for the formation of high school teachers in teaching/learning modern physics. The present work gives a general picture of the course, and a case study of the specific modalities involved in the implementation of some modules, including the main findings.

2 Research questions

The research questions (RQM), upon which the study of the formation model implemented in the different versions of the IDIFO Master's were focused, were:

RQM1. Which system permits high quality e-learning training which is not just a reproduction of face to face training but actually overcomes certain of the latter's limitations and optimizes its potential?

RQM2. How can content and teaching be structured in order to provide effective training for the teachers, and how can the varied requirements of teachers working in diverse situations and socio-cultural contexts be met?

In the light of these questions the different versions of the Master's were systematically researched and analyzed: monitoring the formation carried out in the different stages; gathering the opinions of participants on the educational benefits of the model, using questionnaires and the thoughts included in the conclusions of their project work and in their final theses; analyzing the plans and their trials (carried out with school pupils) and documented online in the final report on each module, particularly in those included in the above mentioned project work and the final reports.

The versions of the IDIFO (IDIFO1/2/3/4) Master's from 2006 on have all been shaped by this research and analysis.

Regarding the formative models adopted in each online module, or at least the formative modules that usually involve the collaboration of two or three teachers, the research questions (RQC) were the following:

RQC1. What is the role of web-based networks in the formation of teachers in educational innovation, particularly in modern physics and transversal themes like formative guidance?

RQC2. Which web-based tools have contributed most to the achievement of the learning objectives of the IDIFO Master's?

RQC3. Which aspects of the online formation were most problematic and what possible solutions might there be?

In order to answer these research questions each formative module was separately analyzed. The forum dynamics and the different levels of interaction between peers were examined, in terms of the level of interaction and of professional expertise construction. The expertise gained in educational innovation linked to the specific themes of the Master's – both regarding design and the implementation of such innovations in real contexts – was also examined.

3. Basic structure of the teacher formation model in IDIFO (1-4)

The two year second level IDIFO Master's was first run from 2006 to 2008 and subsequently, with modifications, in 2010-12 and (currently) 2012-14. The course was developed by the University of Udine's Physics Education Research Unit, under the auspices of the Piano Lauree Scientifiche (PLS), in collaboration with (depending on the year): the Universities of Bari, Basilicata, Bologna, Bolzano, Cagliari, Calabria, Camerino, Firenze, Genova, Macerata, Milano, Milano Bicocca, Modena e Reggio Emilia, Napoli, Palermo, Pavia, Roma La Sapienza, Roma Tre, Salento, Siena, Torino, Trento, Trieste and the Istituto Nazionale di Fisica Nucleare (INFN).

The e-learning activities are run on the uPortal platform, and were developed during the early courses in collaboration with the Artificial Intelligence Research Unit at Udine and then redesigned for the subsequent courses by the Physics Education Research Unit itself.

Other, more flexible, specialization courses (CPs) have been run alongside the Master's in the different years, and on the last two course it has even been possible to take a single course only.

The IDIFO (1-4) Master's and CP project, running in the 2006-14 period (Michelini, 2010b), is a relapse research carried out into physics teaching/learning, at the national and international levels, by collaborating groups, and is also, itself, an object of research. Even though formation in modern physics and

formative guidance are the key elements of all the IDIFO Master's run so far, the need for flexibility in the face of teachers' formation requirements in other areas has led to the inclusion on the formative path of transversal themes, like the RTL experimental laboratory with sensors as extensions of the senses and physics in context. The structure of the IDIFO differs from other online network experiences (Owston *et al.*, 2008; Singera & Stoicescu, 2011) in the following aspects: 1) the professor in charge of each course covered also the tutor role on the platform; 2) integral to the formative modules were a) course participants' project work, carried out in collaboration with the course professors, and b) teaching trials carried out by the participants with high school and university students, documented and discussed on online networks (Michellini, 2010a;b), c) intensive integrative face to face activities, with a variety of methods and objectives (during the first IDIFO course face to face integrative activities were carried out in three intensive workshops involving 60 contact hours in Udine, using a blended model; In IDIFO2 face to face activities in a number of universities integrated web-based activities particularly in regard to experimental workshops, which are obviously impossible to carry out online; In IDIFO3 and 4 face to face activities were offered as separate options at various universities in PLS laboratories in order to broaden the educational offer and allow for customized study paths within the same overall formative model).

The IDIFO formative activities were progressively redesigned in each two year period, while maintaining the common characteristic of containing specific thematic areas, including modern physics and formative guidance.

4 The e-learning environment and online network courses

The IDIFO e-learning platform uses uPortal (homepage can be accessed through <http://www.fisica.uniud.it/URDF/laurea/index.htm>). Its structure has been carefully formulated to best respond to the exacting educational demands of the professional development of teachers.

The platform has both a public area and one restricted to staff and participants. The public access area includes information on the Master's Course, official prospectuses of the Courses, staff members, Council members, and the teaching materials developed over the years and published so that anyone interested can study them. When the IDIFO course was first run the reserved area was divided as follows: 1) teaching modules; 2) participants' designs; 3) trial records; 4) work produced by course participants; 5) common areas including news, memos, circulars and public notices. Experience gained in the first version of the course led to a reduction of the pages in the restricted area of the website shared by the whole Master's, leaving only the pages relative to the teaching

modules, the documentation of trials and the implementation of project work and final reports, and circulars and memos. Participants' plans, and other tasks, are put into practice in the various teaching areas, and are assessed by the teachers of the individual modules.

The teaching staff's access is limited to the modules on which they are teaching, in order to guarantee their own freedom in the designing of their modules and web privacy in general.

Each module is a portlet, developed by the teacher using the recommended basic model and laying out the start/end of the course, the number and structure of the sections, the materials available to participants and the tools available for each section (web-forums, collaborative writing, project delivery folders, links, online tests). Each module includes the presentation of the module (made by the module tutor): its objectives, structure, planned sections and the source material recommended for analysis and discussion, the requirements and work modalities provided for participants and assessment methods and criteria. For each section the professor/tutor organizes 1) online analysis and discussions, source materials on the problematic introduced on the module, 2) collaborative summaries of discussions/debates, 3) interaction between sections of the various modules, 4) preparation of documents on the part of individual participants and 5) definition of analysis and discussion methods. The IDIFO e-learning formation is characterized by: a) discussion of teaching proposals, b) analytical focus on critical points identified in the ample literature on educational research, c) collaborative work by course participants on peer co-managed web forums, d) co-designing by teachers and participants of rationales and materials for teaching trials, e) sharing of materials reformulated by participants and the writing of collaborative syntheses.

Assessments on each module, the responsibility of individual professors, were based on the texts that participants were required to produce for that module (IDIFO 1) or on the set of documents posted online during, and at the end of, the module. The tracking of visits, downloads and general online presence provided the data to verify that participants had taken part in at least 70% of the module's activities, while the assessment of the modules was only related to the quality of participation and of the work accomplished. The assessment includes an analysis of the trials, project work and documents done autonomously by participants and assessed by two referees.

5 IDIF01

The IDIF01 Master's in the 2006-08 period was a formative course in the teaching of modern physics and formative guidance based on recent research into the specific themes of teaching and learning (T/L) for quantum mechanics, relativity, statistical physics, elementary particle physics, formative guidance (Michellini, 2010a;b). It had the following objectives: teachers formation in theoretical thinking and in educational innovations in modern physics; increasing expertise in operative aspects of proposed teaching/learning strategies, focusing on: teaching trials on the problems involved in interpreting 20th Century physics – techniques for material physics analysis, computer modeling and simulation – the preparation and trialing of teaching materials, the development of formative guidance offers to be implemented in schools, based on the problem solving (PS) methodology (Bosio *et al.*, 1998; Michellini, 2010a).

5.1 The structure of IDIF01

The Master curriculum was divided into four areas (general, specific, design and situated) and five thematic modules (Fig 1): a) quantum physics, b) relativity, c) statistical and material physics, d) nuclear physics – particle and cosmological, e) vocational guidance and problem solving.

The course largely took place on online networks, with three intensive face to face educational seminars, whose main role was to: increase expertise in laboratory experimentation in modern physics, face to face debate on the critical points of various themes, the comparison of participants' experimental results, the broadening of the cultural framework through seminars given by researchers from foreign universities.

All participants followed a study path worth 60 CTS – a total of 600 hours – concluding their formation in each of the five thematic modules with a classroom experiment. One of these had to be analyzed in detail and discussed in their final thesis. The study plan included, as well as the assessment of the individual modules, an assessment of four items of project work (PW), one from each of the modules A, B, C+D, and E, and the final dissertations.

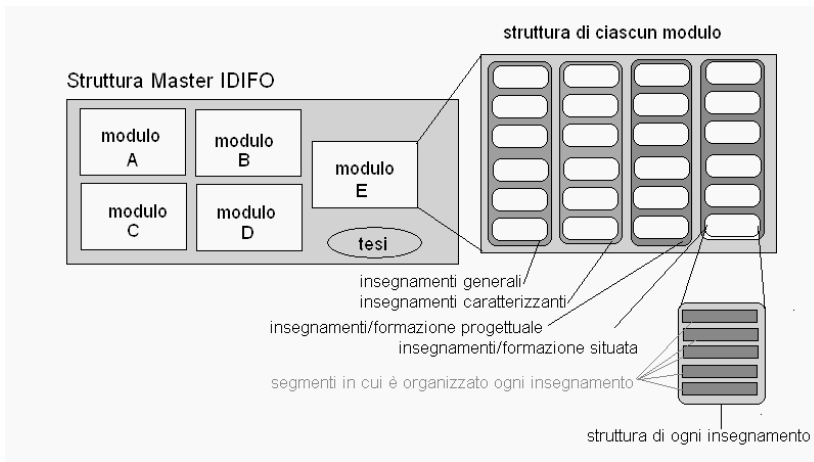


Fig. 1 – IDIFO Master's – organizational chart



Fig. 2 - IDIFO3 Partners

5.2 The individual modules.

Each professor prepared their materials and organized and followed their modules in accordance with the course descriptions on the website. They also discussed and assessed participants' work in the areas dedicated to their modules. Both the general and the specific modules – which aimed to establish the basis of the training offer's framework – in terms of both subject matter and teaching – ran for 2-4 months and were divided into 6-9 sections, each focused on an analysis of a macro-knot. Each student was asked to participate – usually at least two or three times per thread – starting from an analysis of the core

documents, and to post, in the appropriate folders, at least one final document in the form of a completed questionnaire, a summary, a design for worksheets or a study path, depending on the module.

Online discussion of designs and school experimentations, often divided into two or three sections with separate web-forums, took place on certain modules in the design and situated areas. All the source materials for the online formation were published at the end of the Master's, both on the homepage (<http://www.fisica.uniud.it/URDF/laurea/index.htm>) and on paper (Michelini, 2010a;b;c).

5.3 The online tutor

An online tutor followed the entire master course, although he/she never took the place of the teachers in the running of the online environment or in the implementation of the e-learning modules, only intervening if necessary to moderate online communications. They: 1) taught both teachers and course participants to use the platform and prepared a manual on its efficient use; 2) supported teachers in their development of the individual modules; 3) monitored online activity, moderating forum discussions, sending feedback from this continuous monitoring whenever it seemed necessary to restructure the activity, and supporting the teachers in the reorganization of the module, and at its end sent the teachers tables showing participants' principal activities (visits to the platform, written work, downloads, tasks performed).

5.4 Results

Forty-eight teachers from all over Italy enrolled on the IDIFO1 Master's program. The monitoring of online activity was carried out using a range of tools, both to collect quantitative data on numbers of visits, downloads and uploads of documents and to assess participation in the forums using qualitative criteria. This work will be discussed in detail below. The learning outcomes of the face to face activities were monitored through standard tutorials, questionnaires and tests (Michelini *et al.*, 2008; Mossenta & Stefanel, 2010).

The data from the final questionnaire and from their own concluding reflections on their training included in their theses, reveal that the participants felt the e-learning method to be highly effective (67%); they connected this to the opportunity to document and thus systemize their knowledge and to transform these into didactic competencies through the discussion and sharing between professors and participants (at the same level) (60%). The participants felt the phased structure of the forums to be an excellent context, with its coherent and detailed framework, for the analysis of critical points related to subject content (33%) and in the teaching ideas on offer as a basis for teaching and planning

some of the participants found a resource for consideration and reformulation (33%). Documented and asynchronous discussions of colleagues' experiences (80%), on themes usually not dealt with in schools (94%), were identified as being one of the most valuable educational experiences. At the same time 33% of the participants pointed to an excessively heavy workload and some had trouble interacting online, due to the delayed, written form of the peer to peer interaction (13%) and the lack of synchronous e-learning activities, similar to face to face communication (13%). Purely subject related technical analyses were not particularly valued; participants asked for more weight to be given to pedagogy (26%). The experiments in school can therefore be said to have demonstrated the feasibility of online teacher training in educational innovation: the training model is effective and meets teachers' needs, from the point of view of its integration of cultural, subject based, didactic and professional aspects. However, the need to increase flexibility and provide study paths at different levels and with different durations, seems apparent (Michelini, 2004; 2010a;b).

6 IDIFO3

The IDIFO3 Master's (a.y. 2010/11 and 2011/12), which is coming to an end (IDIFO4 has already begun) has been a synthesis and evolution of previous experiences, from which the basic educational framework and the materials developed and published were adopted.

In it the themes of 20th Century physics (above all quantum physics, relativity, with elements of astrophysics and cosmology) and formative guidance (general perspectives and Problem Solving) for teacher training run alongside transversal themes concerning the use of ITC to overcome critical points in physics, training in theoretical thinking and in experimental techniques, the design and execution of physics in context lessons, and the integration of the popularizing of science with teaching. Suggested strategies and methods include laboratory teaching using Inquiry Learning (McDermott, 2001; Abd-El-Khalick, 2004), problem solving (Watts, 1991) and PEC (Theodorakakos, 2010) strategies, the design and use of teaching materials and vocational guidance activities in physics, and ways of analyzing the learning processes involved in educational innovation.

The need to respond to the various educational needs of the course participants and best use the research expertise of the different universities involved, has led to the design of a Master's worth more than 135 CTS, divided into training profiles worth 60 CTS, depending on both general criteria and each individual's training requirements. Face to face training workshops have been added to the e-learning offer on the basis of the PLS methods in operation in

the partner universities. The Master's course involves an exam for each module worth 3 CTS and the presentation of a final dissertations.

The dissertations, presented at the final exam, include the documentation of face to face teaching trials (or online with high school students or other teachers studying the themes of the modules) for at least 36 hours, at least 16 of which must be with the same class.

25 of the teachers had won partial scholarships and chose 60 CTS for their formative profiles. 12 others opted for the shorter parallel specialist course linked to IDIFO3. About 50 teachers attended single courses.

The model for each IDIFO3 e-learning module was as follows:

1. Presentation of a teaching/learning proposal on a particular subject, research based and validated.
2. Reflections on the concepts and the reconstruction of the rationale for the proposal in an online forum.
3. A forum discussion of the analytical perspectives of each participant with peers and teacher.
4. Collaborative planning on a web network by participants, supported by the teacher.
5. Preparation of teaching/learning school intervention (experimentation) in school.
6. Supporting the analysis of data on students' learning processes during the school experimentation.intervention.

The distinguishing features of IDIFO3 are:

1. The design: a modular two year Master's program, with a shorter annual Specialization course, and the possibility of attending single courses.
2. The fact that the program is run nationally, with supervisors in the various universities in charge of the face to face workshops and responsible for supporting the students attached to their universities, thus guaranteeing that all students have readily available assistance if/when it is needed.
3. The local management with diversified activities, which enhance the locations and allow customization of curricula The decentralized management of the Master, that value the cooperating universities and allow customized formative path.
4. The role of the teaching staff, who are both responsible for the formative design and online tutors for the specific e-learning tasks implemented in their particular modules.
5. The Master tutor figure, responsible for: training students in the use of the e-learning platform; interacting with course participants, both by providing general assistance eg helping them to customize their study paths or fulfill particular obligations, and also in single modules, sup-

porting the participants just for organizational aspects and technicalities of the platform.

6. The work done by the participants, carried out through the integration of meta-cultural, experiential and situated models in the various formative stages.

6.1 Cultural context

The choices of cultural field and context is considered to be most important and pressing in the formation of in-service teachers. Indeed for today's cultural politics are connected to 20th Century physics, and the new way of thinking about the world. That it points to: the possibility of new foundations for culture generally, integrating and going beyond the classical, perception based views in its explanations and models.

Relationship between maths and science

The discussion of these themes involves the perception of a new relationship between maths and science. The physics theories of the 20th Century have radically changed ways of thinking within the discipline and pose the problem of the role and significance of formalism in accounting for phenomena. The quantum mechanics of Dirac, for example, overturns the traditional research perspective in which the formalism translates the conceptual interpretations - as occurs in the case of Newtonian mechanics, of mesoscopic models into Fourier's theories of fluids and his laws on phenomena. The Master program offers a specific course on "The role of geometry in physics modeling" and also goes into the connections between maths and physics in some depth in many other courses, for example: "Cosmology from classical times to Einstein", "A geometrical approach to relativity", "Space-time and the dynamics of relativity", "Concepts of relativity: a comparison between the interpretations of Einstein and Minkowski", "A new way of thinking about quantum physics and Dirac's formalism", "The critical knots of quantum mechanics", "Teaching/learning proposals in quantum physics: a comparative analysis", "Quantum physics: teaching proposals linked with field theory", "Rutherford's Backscattering Spectroscopy in the classroom".

ICT and new media as teaching tools

An updating of the curriculum in regard to the use of multimedia tools in the physics curriculum is also proposed. Specific proposals involve educational laboratories with computer online sensors and the real time graphics which facilitate the link between the observation of phenomena and the representation of the time evolution of related significant quantities. These are usually teaching

laboratories in which the computer data gathering is accompanied by computer modeling or simulation activities so that the students are actively and personally involved in the interpretation of phenomena, developing formal models, comparison of the predictions based on these models against experimental data. Three courses focus on the network learning environment, synchronous and asynchronous: “Learning on Networks”, “Installations and live performances”, “New Media”.

Physics in context and communicating science

The thematic area of physics in context has been included, aimed at creating a dialogue between the worlds of school and daily life, with schools offering students expertise in, not just knowledge of, the uses of physics. Therefore some educational laboratories deal with physics in the kitchen, in sport, at the theatre, and also theatre of/on science, an opportunity for its diffusion in contemporary culture. The dialogue between school and the communication of science is another aspect which needs considerable support and which IDIFO3 carried out with the direct participation of the grassroots of the research community and the INFN, which has for a number of years sponsored a conference on these themes, as well as publishing “Asymmetry”, a very useful journal for teachers.

Subject based formative guidance

Previous research into the adaptation of *Popular Problem Solving* by Mike Watts (1991) to different contexts in order to carry out problem solving tasks for guidance purposes allowed for the development of a methodology of formative guidance, implying the personal involvement of the subject in games challenges of open problems. Two courses, included on all the customized study paths, envisage the strengthening of the teacher’s role in guidance, the institutional network idea to create a guidance culture and lay the foundations for the educational design.

The operative stage includes: a) a reflection on the epistemological statute of physics: the nature of the subject and its core principles, in order to create a foundation of useful facts for the planning of a PSO module in physics; b) the presentation, in literature reviews, of the PSO methodology and the educational methods for design; c) the drawing up of individual PSO plans and d) appropriate experimentation in the classroom.

Research into the physics teaching underlying teacher formation

The entire IDIFO3 project is based on the research spin-off into educational methods in physics teaching, which involves four dimensions in teacher formation:

1. Insights into spontaneous interpretative models, learning processes and the difficulties faced by school pupils.
2. Resource for curricular proposals for modules on teaching/learning interventions.
3. Source of tools, methods and strategies for implementing in teachers' planning.
4. Methodological reference for the development of teaching expertise within the framework of Pedagogical Content Knowledge (PCK – Shulman, 1986). 80% of the courses contain research-validated prototypical teaching suggestions and many of the workshops involve the reformulation of teaching proposals deriving from research and also subject to further analysis. The experimentations in school of the paths planned by the student-teachers is analyzed from the point of view, and using the tools of, educational research.

6.2 Modular structure of the formative offer

Figure 3 shows the structures of the courses and their organization into four macro-areas (FM, RTLM, FCCS, OR): 41 courses each worth 3 CTS which allow for the creation of different “organic” study paths, which analyze the subject to varying depths, and leading to different qualifications: a) single courses; b) specialist courses (15 CTS – 4 courses and a project that is trialed in a school); c) Level II Master's (60 CTS – 16 courses chosen by the participants and 2 courses on vocational guidance and one thesis worth 6 CTS, which includes a pilot study carried out in the classroom).

This structure allows each participant to follow the courses most appropriate to their needs and requires a flexible level of commitment, without losing its coherence in terms of formative objectives.

The course structure is transversal and involves co-designing teaching interventions with the teachers and then implementing in school and analyzing them. The teacher formation models included are the meta-cultural model, experiential model and situated models in action-research (Benciolini *et al.*, 2000; Michelini *et al.*, 2005; Michelini *et al.*, 2013) -activity. Wide-ranging transversal cultural themes offer significant new learning opportunities and guidance and create a context in which to understand the broad role of science in different contexts. Important examples are the themes of physics in context, the area of quantum mechanics and superconductivity, the geometry courses, cosmology and general relativity, the courses on live performance and new media. The offer of argumentative activities in the educational laboratories integrates scientific methods and modes with those of maths and philosophy, thus enriching perspectives. Finally, the Problem Solving for PSO guidance is proposed as a model for formative

guidance (Bosio, 1998; Michelini, 2010a).

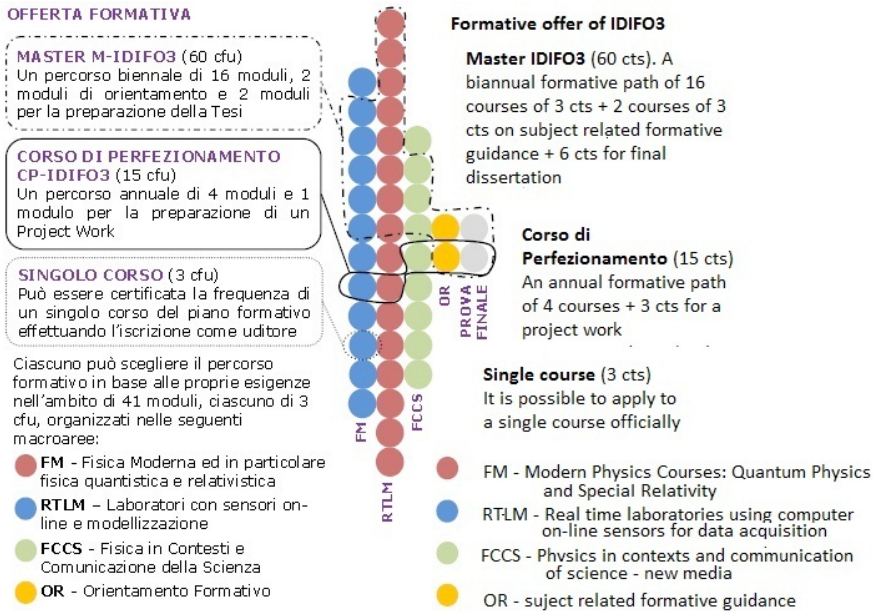


Fig. 3 - Formative offer of IDIFO3. Each participant decide their own formative path, choosing the courses he need under 41 of 3 cts each offered in four macroarees

6.3 Results

As has been said, the IDIFO3 Master's is coming to a close and it is thus now possible to draw some conclusions based on unsystematic data (at present, half of the student-teachers must take the exam in the last session).

It is, however, possible to report some data from the dissertations that have been presented so far.

Although the teaching load in terms of hours of activity has been considerably reduced in comparison with IDIFO1, the commitment required of participants is still huge: much higher than usual for a Master's. On the other hand, the participants have proven to be highly professional and well educated, and very committed to becoming skilled professionals, expert in the areas in which they work. Some were not able to keep up with the workload alongside their teaching work and had to drop out (3), others requested extensions and the chance to repeat modules (6).

In order to allow the teachers who whilst enrolled on the Master IDIFO, to attain a qualification, an annual Specialization course was set up (CP IDIFO3),

borrowing its modules from the master IDIFO3 program itself. It offered a number of participants (7) the opportunity to do a shorter formative course, and also opened the course up to late enrollments. Some of them are enrolled in the Master IDIFO4 to complete their own formative path.

Apart from the overly heavy workload, the formative model implemented proved to be rather effective and appropriate to the needs of the participants, with its integration of cultural, subject content, educational and professional aspects. It integrated meta-cultural, experiential and situated formation, offering all participants a chance for planning development commensurate with their needs and motivations.

7 Analysis of a case study: the QM formative module

At this point, the module dealing with the teaching and learning of Quantum Mechanics, following Dirac's approach, which was offered in the IDIFO1-4 programs, is presented as a case study of the e-learning model. Particular attention was paid to the redesigning of the module and the online interaction dynamics which occurred on the web forum.

In all its different implementations the module was always focused on the analysis of teaching materials and original work from the research project on the teaching/learning of QM in secondary schools, designed in previous studies (Ghirardi *et al.*, 1995, 1996; 1997; Michelini *et al.*, 2000).

The first version of the QM module was divided into three stages:

- Phase A - A1-A2 online courses: based on the foundation concepts of Quantum Mechanics following Dirac's approach and on the presentation and discussion, on a web-forum, of the conceptual knots on which the aforementioned project (Ghirardi *et al.*, 1997) and its worksheets (Michelini *et al.*, 2008) were developed. At the beginning of the course a questionnaire on subject matter and pedagogical competencies required in teaching QM was proposed to the participants.
- Phase B - Face to face meetings with teachers in order to talk about the proposal and the problems which emerged and those left unresolved after the online discussions.
- Phase C - Course B online educational laboratory, aimed at designing a micro module focused on the research proposal analyzed in the previous two phases. In some cases these projects led to experiments in the classroom, implemented as part of the IDIFO Master's formative activities.

The documents discussed in phase A were the articles upon which the propo-

sal (Ghiradi *et al.*, 1997) drew and the tutorials given as part of the same proposal (Michellini *et al.*, 2008; Michellini, 2010c), edited and processed specifically for the discussion. The forum discussions of the online course was divided into different threads, one for each of the conceptual knots on which the educational proposal under analysis focuses.

In addition to the proposal of reference of the module discussed here, the participants on IDIFO1 and 2 were offered formation on three other different approaches to teaching and learning QM at school, thus ensuring a broad perspective on the teaching of QM. Two main critical aspects of the first implementation of the module was: the course A1 on the analysis of the conceptual foundations of the MQ, as judged very interesting by the student-teachers on the scientific level, has had only a slight impact on the CK of the student-teachers. The construction of PCK has been activated in the designing phase when the student-teachers set-up the learning paths that they implemented in the classroom, through the reconstruction of conceptual contents focused on the teaching/learning proposal that was being experimented. b) although the students/teachers was offered four different approaches, the international research on teaching/learning MQ in High School remains out of the formation.

In the subsequent versions, the module was implemented completely in e-learning and redesigned aiming to ensure: a systemic integration of the reconstruction of the contents and the teaching/learning proposal offered as a referent; a comparative analysis of the research proposals given in the literature; entire formative paths online.

According to this aims, the QM Module in the Master IDIFO3 was organized in the following three courses:

- A1-Course: A new way of thinking about QM and Dirac's formalism (online analysis and discussion of the teaching/learning referent proposal for QM (Ghiradi *et al.*, 1997).
- A2 Course: conceptual knots in QM (Starting from the analysis of the questionnaire on QM points filled in at the beginning of the previous course (Francaviglia *et al.*, 2012), discussion of the main critical points with the aim of designing proposals for experiments in high schools)
- A3 Course: Proposals for the teaching of quantum physics: a comparative analysis (a comparative critical discussion of research based proposals in literature, starting from research reviews (Styer, 1996; Zollmann, 1999; Stefanel, 2008; Pospiech *et al.*, 2008).

The A1 course was divided into three stages. In the first (02-12 Feb. 2011) the student-teachers, in the web forums, analysed and discussed the papers presenting the teaching proposal (Ghiradi *et al.*, 1995; 1996; 1997; Michellini *et al.*, 2000), the web site designed to support the teacher formation and the

educational repository for the proposal (Michelini *et al.*, 2002). The debate developed on two levels: firstly that of the cultural and conceptual choices involved; secondly at the didactic level. The second stage (10-14 Feb. 2011) involved a critical analysis of the tutorials, which translate operatively the referent proposal and is an integral part of it. The experiential formation to use them, as did the students who have experimented (now in over 20 classes) brought out the thread of reasonings in each step and offered the chance of discussing the most important aspects of the new way of thinking about theoretical physics. The third stage (15-20 Feb. 2011) was devoted to discuss content and teaching methods from the perspective of the educational design.

The discussion in the three modules of the A1 courses was divided between six web-forums (WF1-6). Here we focus on the first of these:

WF 1) The choices made: their cultural significance and limitations. The aim was to analyse the value and limitations of the proposal from a cultural perspective, in the light of other known paths and in particular of the proposals already followed the course A3 on Teaching/learning proposal of QM in comparison. Two requests: A) a personal perspective starting from the teaching proposal; B) ideas stimulated by colleagues' comments.

The other WF focuses on the curricular choices made, the educational tools used (Ghirardi *et al.*, 1997; Michelini *et al.*, 2000; 2008), the concepts learned and criticism, the relationship between real and ideal experiments and the role in the proposed educational path and other fields of physics, and the design educational project.

The course A2 was structured around an analysis of the conceptual knots of QM. The course A3 was based on an analysis of different proposals about QM at the undergraduate level, based on review papers (Styer, 1996; Zollmann, 1999; Stefanel, 2008; Pospiech *et al.*, 2008).

7.1 The theoretical hypotheses

Knowledge creation, although a process in which an individual is engaged in a voluntary act of learning (Bransford *et al.*, 2000)), is facilitated by debate and exchange (Doise & Mugny, 1986). Such debate can now take place through Computer Supported Collaborative Learning. The theory upon which this methodology is based is that learning in a collaborative group occurs through – or is at least greatly enhanced by – debate, and even dispute, about different points of view, with varied contributions, arguments and counterarguments, requests for clarification or explanation, detailed analysis.

The theory is that people are stimulated to reformulate their own thought patterns (Calvani *et al.*, 2007). According to the perspective adopted in IDIFO, the discussion of critical points related to the themes being debated and reflection on analysis of educational research proposals focused along different lines can develop both specific content knowledge (CK) and pedagogical content knowledge (PCK) (Shulman, 1986). The theoretical and methodological system of online collaborative learning has favoured the use of threaded web forums (Calvani *et al.*, 2007), whose basic features offer important functions for the development of online discussions about learning: the fact that documents remain on the site for a long time and can thus be reviewed and revised and reanalyzed and links can thus more easily be made between ideas, fosters reflection (Salmon, 2002; Dillenbourg, 2005; Calvani, 2005).

Some significant limitations must be kept under control in the planning stage and be countered by tutoring: incoherence, lack of focus, lack of agreement of synthesis in discussions, little correspondence between the representation of a subject and the conceptual representation of the knowledge being created (Calvani *et al.*, 2007).

7.2 Methodology for analyzing online interaction

The most frequently used methodologies for studying online interactions involve the quantitative analysis of data through the classification of individual messages according to pre-established codifications and the analysis of the distribution of categories revealed (Rourke *et al.*, 2001; De Wever *et al.*, 2006). Qualitative methodologies, like those used in ethnographical surveys (Schegloff, 1989; Sacks, 1992; ten Have, 1999) are very costly and are rarely used. Calvani and his collaborators (2007) proposed a model based on the quantitative analysis of 5 indicators of participation (the extent of participation, sense of purpose, participatory impartiality, the range of roles, rhythm) and 4 indicators of cohesion (legibility, depth, attention to purpose, conclusiveness). This form of analysis seems to be an effective way of comparing the level of interaction and collaboration in the different sub-groups of the same set of individuals, in other words of comparing these factors in a web-forum taking place in the same formative context.

Hara, Bonk and Angeli have proposed an alternative classification based on the type of data (Hara *et al.*, 2000; Burton & Martin, 2010) to assess the level of collaboration that has been enabled. Hrastinski (2008) has proposed an integration of this classification to simultaneously assess levels of communication about content.

This paper adopts the latter analytical methodology in so far as it is responding to the need to have both an estimate of the level of interaction and colla-

boration and a picture of the areas of discussion.

Particular attention was paid to the following categories:

- A Questions (interventions focused on an explicit question).
- EC Elementary clarifications (observations or comments relevant to the particular theme, which show the acquisition of a detailed knowledge of the critical points being discussed).
- DC Deeper clarifications (observations or comments relevant to the particular theme, which show the acquisition of a detailed knowledge of the critical points being discussed).
- II Inferences (interventions which show that the theme in question is being elaborated upon).
- G Judgement (interventions which include decisions or assessments of the theme in question).

Each category was divided into sub-categories, according to whether the interventions regarded content (-C) or didactic aspects (-D). Only the questions were examined regarding their technical-organizational aspects (TO). Interventions which were not pertinent to the theme in question (OT) were considered separately, as were interventions limited to acknowledging a contact or the insertion of a document in a specific folder of the document repository (INF).

The tutor's interventions were classified according to the typical roles of a tutor (Lima & Cheaha, 2010; Taylor & Maor, 2000; Guldberg & Pilkington, 2007; Losito, 2004;):

- I – setting tasks
- R – replies, on “technical” aspects of the online discussion (R-T); on content (R-C); on didactic points (R-D)
- FB – feedback, stimuli, raising questions, critical comments to stimulate reflection on content (FB-C) and didactics (FB-D)
- FO – interventions to keep discussions focused.

The quantitative data for each participant were gathered, and those for each type of intervention. In addition to the overall data for the different threads of the web-forums, charts recording the development over time of the discussion on a thread of particular significance, both from the point of view of communicative interaction and that of the content dealt with, were created.

To assess the amount of interaction occurring on the web-forum, the adjusted mean reply depth (ρ) (Wiley, 2004; Calvani *et al.*, 2007) was used, here defined:

$$\rho = \sum_{i=1}^m n_i w_i \quad \rho' = \left(\frac{N-b}{N}\right) \sum_{i=1}^m n_i w_i$$

where N = total number of contributions, b = initial contributions without development, n_i = numbers of contributions at level I , w_i = weight of the contribution level ($w_i=(i-1)/N$).

The last level of analysis was applied to the content of the contributions, as was done in previous research on web-based teacher formation (Battaglia *et al.*, 2011; Michleini 2010a).

7.3 An analysis of the module on the Dirac approach to Quantum Mechanics in IDIF01

Below follows an evaluation of the formative module on QM which ran as part of IDIF01, with 22 participants. The forum discussion was launched by starting a thread for each of the nodes from which the proposal developed. Active participation on the web-forum of the online A1 course is recorded, consisting of 266 interventions by the 22 participants, (an average of 12 per participant, $\sigma=2$), distributed as shown in Fig 4. The spikes connected to the F2 threads on the probabilistic interpretation of quantum processes and F3, on the dynamic properties of quantum systems, are clearly obvious.

In the F3 forum thread, which is given as an example, 18 participants made 42 interventions (2.33 per participant, with a minimum of 1 and a maximum of 8), in which 5 main sub-threads can be identified, and are classified as shown in the table below. Most of the interventions are elementary classifications (EC – 17 in total, 12 on content and 5 on didactics) and questions (A – 11, 5 on didactics, 2 on technical-organizational aspects and 1 on content).

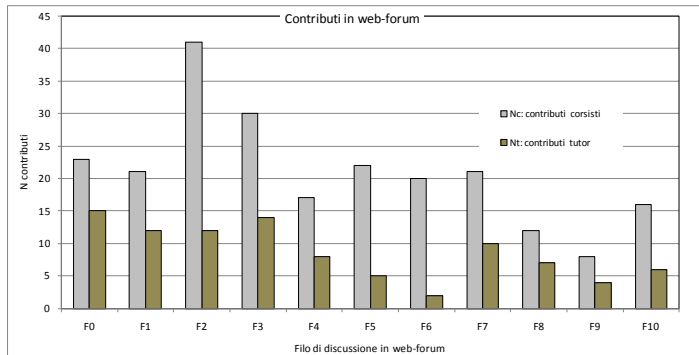


Fig. 4 - Contributions of the 22 participants and the tutor. FO – Test; F1 – Polarization; F2 – Probabilistic interpretation; F3 – Dynamic properties of a quantum system; F3 – Interpretative hypotheses; F5 – Quantum and trajectory systems; F6 – Incompatibility and mutual exclusivity; F7 – States and vectors; F8 – Observable and linear operator; F9 – Generalization, F10 - Nonlocality

The dynamic of the discussion in the F2 forum is clearly shown in the diagram in Fig 5, which also shows the type of intervention, classified as previously explained.

The focus of this thread was more on context (24 interventions) than on didactics (13 interventions) and in particular on the following themes: the conceptual role of single photon experiments; the intrinsic stochasticity of microscopic processes; the nature of QM and the role of formalism. 19 of the interventions were actually short texts (of 10 - 40 lines) which involved more sub-threads.

The dynamic of interaction between the participants can be seen both in the diagram in Fig 4 (intervention cluster: 6-8, 12-19, 23-47), and in Table 1, where a preponderance of EC – elementary clarifications and DC – in depth and a limited number of A - questions emerge. Some interventions are also shown not to be pertinent to the theme (OT).

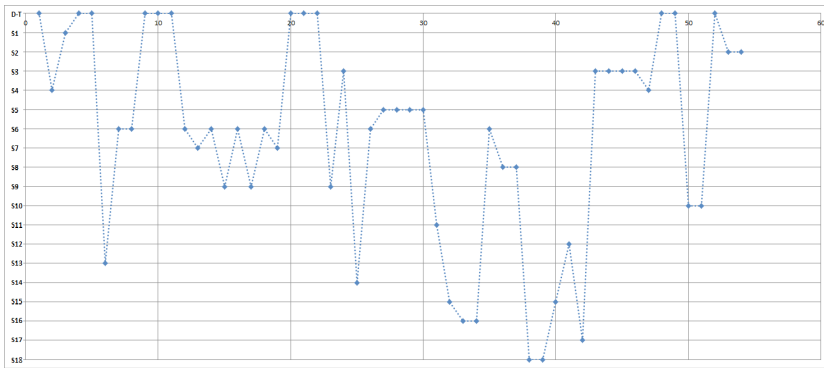


Fig. 5 – the development of the 54 interventions on the F2 forum, with indicators of the category and author (D-T: tutor; S1 – S18: participants) of each message.

It is evident that, once started by the tutor, the dynamics of the discussion developed autonomously (and were not always pertinent to the theme under discussion). Both this autonomy and the difficulties found in staying focused on a specific theme are characteristic of the groups of highly qualified teachers who attend the courses.

Table 1

TABLE SHOWING THE TYPES OF INTERVENTION MADE BY PARTICIPANTS IN THE F2 THREAD OF THE FORUM. IN THIS FORUM THE TUTOR'S INTERVENTIONS WERE OF THE FOLLOWING TYPES: I (1), RT (1), RD (1), RC (1), FBC (3), FBD (4), FU (1)

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	tot	
EC-C			1	1	2			1	2		1		1		1				2	12
EC-D		1				1	1				1			1						5
DC-C					1	2					1						1			5
DC-D						1						1								2
II-C						2			1						1	1				5
II-D								1												1
G-C						1														1
A-C		1																		1
A-D			4															1		5
A-T	1			1																2
OT			4			2			1										1	3
TOT	1	2	5	2	4	8	2	2	3	2	1	1	1	1	2	2	1	2	4	42

The 266 interventions, made by 22 participants in the 11 discussion threads into which the forum is divided, were classified as shown in Table 2. It shows (2a) that the same categories dominate as did in F2, with a lower content/didactics ratio (closer to 50%) and more complex and in-depth contributions, and also questions on content. These elements can be explained by the fact that most of the questions on content were asked by those participants with weaker academic backgrounds, while those with solid backgrounds felt more of a need to clarify didactic issues, although they were able to contribute to the forum debate with intelligent interventions expressed in their own words. The relatively high number of INF interventions in the last forum was due to the many interventions in which the integration of the network map is pointed out.

Table 2

TYPES OF INTERVENTION MADE BY PARTICIPANTS (ON THE LEFT) AND B) BY THE TUTOR (ON THE RIGHT) IN THE DIFFERENT DISCUSSION THREADS OF THE WEB-FORUM

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	Map	TOT
EC-C	6	12	10	1	3	1	5	4	3	2	9	56
EC-D	2	5		1		7	2	1		5	1	24
DC-C	9	5	4	5	14	4	2	2	2	2	8	57
DC-D	2	1	2			3		1				14
II-C		5	6									11
II-D		1					1					3
G-C		1										2
G-D												2
A-C	1	1	10	6	4	4	5	2		4		40
A-D	2	5	1	1	1	1	4	2	3	3		23
A-TO		2		1								8
OT		3										3
INF	1				1							21
TOT	21	42	32	17	23	20	19	12	8	16	56	266

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	Map	TOT
I	3	1										4
R-T		1									2	3
FB-C	6	3	2		4	2	1	2	2	1	2	25
FB-D	1	4	1				1	1				8
FU		1										1
R-D		1	2	4			5	3	2	2		19
R-C	1	1	8	4	1		5	1		3		24
TOT	11	12	13	8	5	2	12	7	4	6	4	84

The preponderance of type R (replies to participants' queries) interventions and feedback from the tutor (2b), particularly on content, shows the double role played in the forums by the tutor, who is both the initiator of discussion

and the expert.

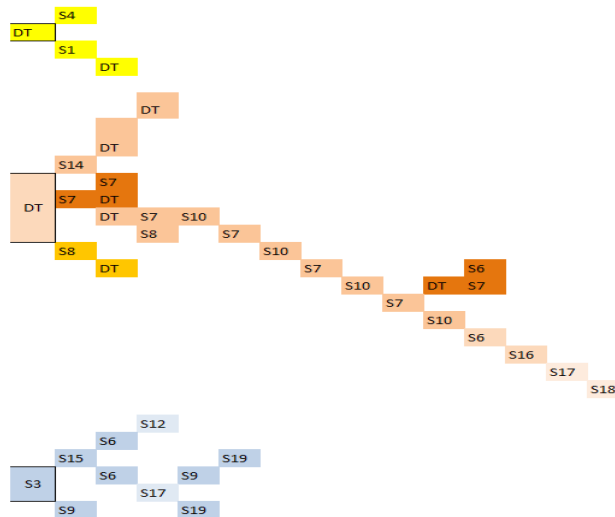


Fig. 6 - Tree diagram for the web form contributions.

An analysis of the tree diagram (fig. 6) of the responses demonstrated that the forum discussion develops from 3 different roots, with a main thread which develops out of the tutor's initial intervention.

This structure explains the high value of the response coefficient $\rho = 175$, against a mean connectivity of 2.3.

The greatest benefits of the forum discussion were however the achievement of a rate of knowledge socialization regarding both subject content and teaching expertise. The forum allowed participants to familiarize themselves with the problems around QM and to share and debate their ideas on these and on the related pedagogical problems, to modify the participants' understanding, shifting it from the pedagogy of quantum physics to a more specific awareness of the fundamental points of QM. This attention translates into professional expertise in the planning stage, which is shared and discussed online (Michelini, 2010a; Battaglia *et al.*, 2011).

7.4 An analysis of web-forum 2 of the IDIF03 module

Here we look at the interactions that took place on WF1 of the A1 course of the module on the teaching and learning of QM, on the IDIF03 course. 14 of the 22 participants enrolled on the course contributed to the WF1, with $N=27$ contributions. Each participant intervened between 1 and 4 times, with a mean

value of 1.9 ($\sigma=0.8$). The tutor set up the forum, assigned the task and left the discussion to develop freely between peers. The graph in Fig. 1) shows the sequence dynamic of the discussion, to which 9 participants contributed with 2-3 interventions.

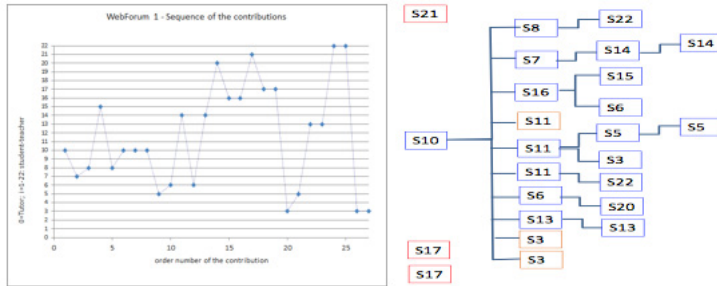


Fig. 7 – Sequence of the contributions in the web-forum 1 of the course A1 (on the right) and tree structure of the web discussion in WF.

The tree diagram analysis (Fig. 7) shows that the participants' contributions all started from just one of the four initial contributions posted on the WF 1 and developed 7 branches (from 1 to 3 ramifications). The mean reply depth is equal to $\rho=1,4$ and the mean number of links was 0,9. The two analyses show a low level of interaction in the forum, but this is not borne out when the post content is considered. The contribution types, analyzed according to Hara et al. taxonomy (Hara *et al.*, 2000; Hrastinski, 2008; Burton & Martin, 2010), are summarized in fig. 8, where the mode (1/2 of the contributions) corresponds to elementary contributions, and 1/3 of the contributions fall into the category of in depth contributions. In both cases the focus is on didactic aspects. For the participants, the cultural value of the particular offer on QM is primarily related to the educational choices made, and less to the choice of content or the theoretical approach.

The correlations become evident when the subject content of the interventions on different roots is examined. For instance, three of the contributions are very similar in their stressing of the effectiveness of the particular offer: S21- Evaluation of the proposal: similar to others analyzed; "Positive because free of interpretation"; S10 – "The path is similar, at least in the beginning, to two paths [27-27] that I analyzed on the A3 course. I chose "attracted" by the type of approach, which reflects that of the proposal", S17- "effective for learning, need to integrate with other examples".

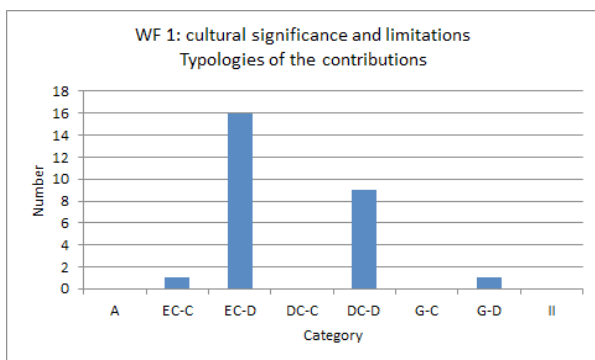


Fig. 8 – Classification of the contributions: absolute frequencies of the types.

Moreover, two contributions stress that the proposal should deal with the core of the theory, starting off with simple experiments, and breaking with classical physics, an aspect which emerged in five other contributions. Finally, two contributions stress a critical point of the path on the need to explain the existence of photons: S20 and S3-“Müller, Wiesner (2002) deal with the photoelectric effect in order to introduce the concept of the photon, while in Michelini Santi Stefanel (Ghirardi *et al.*,1997; Michelini *et al.*, 2000; 2008) the fact that light is composed of photons is taken as knowledge that pupils need to have.

The richness of the web discussion emerges from an examination of the content of the posts, both regarding the value of the proposal for student learning, the phenomenological context of light polarization phenomenology and suggestions on how to integrate educational paths: the need to generalize (other contexts suggested: double slits; Mach & Zender – 4 cases). There were only 2 posts on Schrödinger’s Equation; and only 1 on application, and 1 on historical reviews (almost at the end).

Conclusion

Educational innovation in physics requires close collaboration between schools and universities with a view to carrying out research at various levels: Institutional, Organizational, Structural, on Context and Methods, on recognition of the value and role of the work carried out in the different institutions. The IDIFO Master’s on educational innovation for in-service teachers was planned and offered to teachers in Italian schools as a contribution from research. It itself was, in turn, an object of research, and context and instrument for collaboration of research units from Italian Universities, national research institutes and schools.

IDIFO makes a contribution to educational innovation, particularly in schools, for the following reasons: it puts into the field educational laboratory stra-

tegies, multimedia and new ICT to overcome the conceptual knots in specific fields of physics; modern physics and physics in context, features and role of formative guidance and the contribution of physics education research to learning and to teacher formation.

The teacher formation model involves the integration of 3 main models: meta-cultural, experiential, situated; research findings demonstrate that this integration does not provide teachers with sufficient preparation to become expert in the field of educational innovation. Factors essential to the formative process are: reflection on the core concepts of theories, the reconstruction of the interpretative approach to phenomenology, comparisons of different teaching/learning proposals, documents of shared synthesis and planning drawn up collaboratively and discussed in the light of the diverse didactic strategies and practices which are accessible almost exclusively through e-learning.

The experience of the IDIFO Master's and CP's has shown that e-learning formation is invaluable for the collaborative creation of teaching interventions, whose efficacy in the development of collaborative skills, group communication, the control and management of one's own learning, time management has been documented (Fera *et al.*, 2011). In particular, it provides ways around the rigidity of PCK strategies for teacher formation regarding didactic planning and redesign in the scientific field, indispensable for the process of appropriation. These factors clearly compensate for the criticisms made of the distance-training - the lack of direct relationships between people, non-verbal communication and immediate feedback – which are, in fact, resolvable through specially designed tutoring strategies, as was done in the recent versions of the IDIFO.

Concerning the research questions, it emerges that the contribution of the web-based activities (RQC1) is crucial to participants' reflection on and consequent consolidation of new perspectives on both subject-related aspects and transversal tasks, like guidance. The radically different way of thinking about some key concepts, i.e. that of state in Quantum Mechanics, the principle of superposition and the concept of measurement, in comparison with that of classical mechanics, led to the reformulation of the teaching plans of 75% of the participants. All the participants modified their understanding of the nature and role of formative guidance, although the redesigning suffered from a lack of incisive face to face debate, compared with the identification of indicators for the guidance character of the planned subject-based educational paths (30%). Network-based activities facilitate collaborative learning and planning, but also they increase workloads. The customization facilitated by network-based activities gives all members of a community the opportunity to increase their expertise, as was particularly clearly demonstrated in the development of the QM module.

The most powerful tool for the achievement of the goals of the IDIFO Ma-

ster's (RQC2) is the web-forum, as long as it is structured in such a way that the themes of discussions are broadened and focused synthesis is facilitated. Discussion strengthens participants' reasoning abilities, thereby also increasing their educational capital in the scientific field. The greatest benefits of the forum discussions were the achievement of a high level of knowledge socialization, of both the subject matter and teaching expertise. The forum allowed participants to familiarize themselves with critical points related to subject matter and to transversal aspects, to compare and share ideas about these and about related pedagogical problems; it allowed for the modification of participants' understanding: this translated into increased professional expertise in the collaborative design stage, carried out online. 30% of cases retained aspects of unfocused planning, in comparison with much higher percentages after other forms of training (Michelini *et al.*, 2004; Michelini, 2004; Bryan, 2011).

The most critical aspects of online formation (RQC3) are closely related to its organizational structure, as the distinction between the modules putted in evidence. The most critical formative objectives are those related to the change of cultural perspective and style teacher professional. Demanding, laborious work on the web-forum combined with collaborative writing favour a more profound and lasting process of cultural and intellectual change than would occur in more trenchant and immediate face to face discussions (RQM1). This is the case in which blended activities proved fruitful, through the face to face workshops and integrative laboratories. It remains at a qualitative level the belief that more research is needed to identify flexible and streamlined learning and conceptual change strategies of student-teachers without losing the recognized educational benefits of the online formation (RQM1). The context of the IDIFO1-4 Master's and CP's as a research field into formative models of in-service teacher has highlighted the need to develop and run differentiated, flexible courses, in which e-learning plays an important role (RQM2).

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