DIDACTIC PLANNING WITH BLENDED ACTIVITIES IN A WEB INTERACTIVE ENVIRONMENT: THE CASE OF SIMPLE MACHINES WITH TEACHER-STUDENTS FOR PRIMARY SCHOOL

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1. Introduction

Scientific and technological skills, problem solving abilities, teamwork, creativity and flexibility have been identified by the European Community as the conditions for development centred on human resources [1]. Nevertheless, there seems to be a risk that the professional culture of physicists may get lost, and what is worse, that common people cannot appreciate the cultural value of physics and cannot be aware of its relevance to everyday life.
This situation is a consequence of the way science has been taught till now. For future young generations, physics education should start very early, together with the first experiments in observing and representing reality, both at nursery school and at primary school, and it should be especially targeted to teachers, who should be educated to apply physics concepts in viewing reality as well as in designing children's education.
Particularly in scientific learning, literature highlights that new teaching strategies are needed to produce a conceptual change from common sense to a scientific outlook on phenomena [2, 3]. The non-connection between everyday experience and schoolwork in the scientific field has been identified as the main cause of children's learning difficulties [4,5]. Therefore experimental exploration and personal involvement are important components of the construction of knowledge as an individual interpretation of reality [6]. Negotiation and sharing of meanings are the basic elements of learning [7].
Pre-service education and teachers' training started in 1998 in many Italian universities, more than eight years [8] after the law which had instituted them (Law no. 341/1990) and the inspiring principles of which anticipated the university reform started in Italy in the academic year 2000-2001. This is an opportunity that should not be missed, since new generations of teachers may be provided with a knowledge of physics which is firmly anchored to their professionalism and which may therefore be effectively used in children's education.
Educational design is one of the main skills required of teachers. One of the main issues to be dealt with in pre-service training of primary school teachers is to provide them with basic scientific culture which may enable them to perform successful educational design in spite of their limited knowledge of the subject.
Recent studies on the training strategies for teachers undergoing pre-service training proved the necessity of dealing with a subject by means of didactics, carrying out training activities which include design and educational issues. The direct involvement of the trainees in the subject matter, the manual and conceptual participation required of them in the interpretation of the subject, the shared analysis of the potential and of the limits of interpretation, are basic conditions for learning [9].
An ideal context for providing teachers-to-be with training in educational design and peer cooperation is a flexible and interactive web-based environment allowing synchronous and asynchronous distance communication, boosted by preliminary face-to-face joint work carried out according to a detailed work-plan. This work modality can enable trainees to manage their professional growth by means of a community of practice.
A joint experiment of this kind was carried out by the Universities of Reggio Emilia and Udine within the course in *Design of Educational Experiments* which is common to the degree courses in

Education of both Universities. During the experiment a model of blended activity and a prototype of interactive web-based environment were developed. The web-supported joint activity consisted in three main tasks assigned to the students: i) in-depth study of an assigned topic; ii) search for experimental solutions; iii) joint design of educational paths.
The topic chosen for the experimentation was simple machines. The research issues this paper deals with are the students' ideas and expressions on simple machines emerging from the web-supported joint work, and the modalities for the transfer of the basis of science acquired by the students into an educational context.

2. The work context and the cooperation

Research collaboration is ongoing between teachers of the degree course in Education of the Universities of Udine and Modena-Reggio Emilia, aimed at designing and testing new strategies and methodologies for the teaching of Physics [9]. Within the framework of this joint work, an experiment was carried out in the academic year 2004-2005, in order to analyse face-to-face and distance interaction between students belonging to both Universities.
The experimentation took place within the course in *Design of Educational Experiments*, which is common to both Universities and aims at training teachers-to-be to design laboratory-based teaching activities and educational paths.
The two courses were carried out during the same period and according to the same syllabi, in order to enable the about 70 students involved in the experiment to perform both face-to-face and distance synchronous interactions.
Face-to-face activities were carried out as follows:

i) a multi-context experimental work involving students from the same University, focussed on measurement issues, identification of regularity, and on the methodological layout of the experimentation;
ii) a joint work in experimental activities bringing students from the two Universities into contact with each other. The activities were performed in Udine during the 2005 edition of the Week of Scientific Culture, by means of the cards and equipment of the GEI (Games, Experiments, Ideas) exhibition (www.fisica.uniud.it/GEI/GEIweb/index.htm). Moreover, during the last part of the course, the students of both Universities performed a network-supported distance cooperation, carrying out a three-phase activity to perform joint design of educational paths on simple machines.

The focus of this paper will be on the network supported distance cooperation last part of the formation intervention.

3. The environment

Former research showed the crucial role of educational design - meant as a reworking of reference documents and materials - for the learning of scientific subjects by teachers-to-be [9] in that it can foster the development of their professional competences and skills by integrating science subjects learning into them.
The web-based environment used for the experimentation was designed and customized starting from the above described educational needs; it includes conferencing and discussion tools as well as training materials, documents and tools, in which the students can find a wealth of examples. It requires formal registration, after which the users are given a personal identification password for logging in.
The environment is organized in three main areas:

i) operational area, containing the tools necessary for communicating and for performing activities;
ii) organizational area, containing the information and the tools necessary for the management of the activities;
iii) reference area, containing the reference documents relevant to the subject.

A variety of tools are available to the users, ranging from asynchronous communication tools such as web forums, internal messaging and *scricoll* (a tool for cooperative writing) to synchronous communication ones such as chats. Moreover, it is possible for the users to deliver additional materials to the three areas, and to create several kinds of maps (conceptual maps, organizational maps, etc.) by means of a specially provided software.
The materials for educational design made available to the users were produced in the course of several studies carried out in the field of scientific didactics and informal education [10], which can be found in the webpage www.fisica.uniud.it/URDF/. Links to science-related websites containing reference documents and samples of projects, courses and teaching units on relevant subjects, were also provided and regularly updated.

4. Work methodology

As has been mentioned above, after attending the face-to-face part of the course the students performed web-supported distance cooperation aimed at designing educational paths on simple machines.
The task was organized into 3 consecutive phases.
Phase I, which lasted 11 days, dealt with the in-depth study of the subject: the students had the task of analysing the physics concepts underlying simple machines, using the resources available to them and discussing them through web forums, document archives, and chats.
Phase II, which lasted 13 days, dealt with the search for and discussion of experimental solutions: starting from their common experience and from the resources available to them, the students were assigned the task of identifying possible experimental activities for the teaching of simple machines in primary schools. In this phase, too, the task was carried out by means of web forums, document archives, and chats.
During Phase III, which lasted 7 days, the students split into 8 different-sized groups (varying from 2 to 13 people) and worked together to design as many educational paths by means of the *scricoll* tool for cooperative writing. The scheme for drafting the paths was drawn from the one carried out within the SeCiF[1] project and was made available in the *scricoll* as a starting point for the students. It was composed of the following sections:

- Introduction (remarks on the educational, methodological and scientific assumptions)
- Methodological layout
- Approach
- Strategies and methodologies
- Prerequisites
- Conceptual map /Organizational map
- Thread (educational path sequence)
- Activities to perform
- Conceptual cruces and learning challenges
- Educational tools

All of the three work phases were attended by a network assistant to provide explanations and to solve possible problems. As a rule, the assistant did not intervene in the process on his own initiative to correct or to steer the works except at the beginning and at the end of each phase.

5. Results

This section contains an analysis of the materials produced by the students during their web-supported distance cooperation. The research issues have been dealt with as follows:

[1] **SeCiF** is an acronym for the Italian *Studiare e Capire in Fisica* (*Studying and Understanding Physics*), a PRIN project in which 9 universities took part, aimed at producing educational projects for the teaching of Physiscs. The materials produced by Udine University are available under the SeCiF icon at the page: www.fisica.uniud.it/URDF/

- as regards the students' ideas and expressions on simple machines, information was drawn from the messages sent by the students into the web forum during Phase I and II of the activity;
- as regards the modalities for the transfer of the basis of physics thus acquired to an educational context, the educational paths jointly designed by the students were analysed.

The quantitative statistical data on the quality of the web-supported cooperation performed have been described in depth in a former paper [11] and will therefore be only touched upon herein.

5.1. Students' ideas and expressions on simple machines - Phases I and II: Web forum

During the first two phases of the activity the students performed individual on-line work, taking part into several discussions launched and managed by themselves in the web forum. Each student willing to propose a new topic was supposed to fix a title for the discussion and to write the first message; the participants could join the discussion of a topic either by proposing discussion strands (first-level messages) or by replying to messages on any level.

Phase I (in-depth study of the subject) was attended by 76 students. 88 discussion topics were proposed (not all of which were different) and 398 messages were sent; on average, 1.2 topics and 5.2 messages for each student, and 4.5 messages for each topic.

Phase II (search for and discussion of experimental solutions) was attended by 69 students. 76 discussion topics were proposed (not all of which were different) and 330 messages were sent; on average, 1.1 topics and 4.8 messages for each student, and 4.3 messages for each topic.

The extent of the cooperation performed was assessed through the ramification index [12] considering the structure of the discussions on the selected topics: the more the students participated in the discussions (i.e. replied to messages sent by other students) the higher the numerical value of the index. Discussion topics containing less than 4 messages were ruled out because the value of the index is not significant if related to such a low number of messages. Moreover, in most cases, such topics had been created by mistake and were also contained in other discussions relevant to other topics.

The ramification index remains steady at about the middle of the allowed minimum-maximum interval (i.e. no theoretical cooperation-maximum theoretical cooperation), showing a good level of cooperation among the students (several discussions were launched, and messages and replies were sent by several students) and thus proving the significance of the results of the qualitative analysis carried out on the contents.

The qualitative analysis of the contents was carried out by grouping similar discussion topics in macro-topics, thus performing a partition within the whole of the original topics. 7 macro-topics and all the relevant messages were identified and analysed. Three out of seven topics refer to physics concepts (force, torque and mechanical equilibrium); one concerns simple machines, and the remaining three deal with as many kinds of simple machines (lever, screw, wheel and axle).

Table 1 shows the percentage of information provided by the students for each of the 7 macro-topics, according to the character of the information:

i) *formal definition*: mention of the relevant physical quantities and of their connections (e.g. "the torque to a point is the result of the intensity of the force multiplied by the distance of the point from the line of action of the force");
ii) *qualitative description* of relevant aspects or details (e.g. "a wheel and axle is made by a grooved wheel with a rope running over it");
iii) *classification* (e.g. "there are levers of first order which ......; levers of second order which .....; and levers of third order which ......");
iv) *listing* (e.g. "levers of second order are: nutcrackers and wheelbarrows").

Table 1

MACRO-TOPIC / CHARACTER	FORCE	TORQUE	EQUILIBRIUM	SIMPLE MACHINES	LEVER	SCREW	WHEEL AND AXLE
Definition	36%	80%	83%	52%	66%	27%	44%
Description	27%	20%	17%	26%	28%	64%	33%
Classification	N/A	N/A	17%	9%	24%	18%	44%
Listing	N/A	N/A	N/A	17%	31%	N/A	N/A

N/A = not applicable

The table shows that the students involved in the experiment tend to quote definitions when dealing with unfamiliar concepts such as torque and equilibrium: it is as if they tried to seek refuge in ready-made expressions in order to shirk responsibilities and to avoid personal formulation of concepts, confining themselves to mere quotations of statements and showing no in-depth knowledge of their meaning. For the same reason the concept of force, which requires deep critical comprehension skills bound up with a mental model, is dealt with in a descriptive way.

Simple machines appear to be a more familiar ground to the students, though they mostly deal with this topic by means of non-formal verbal expressions. They also provide descriptions, classification and listing.

As regards the three kinds of simple machines it can be noticed that the students tend to describe and classify them rather than analysing them from a physical point of view. This reveals their difficulty in connecting formal learning – namely physics concepts – with commonly used everyday objects.

Absence of any reference to units of measurement in the students' comments should also be remarked.

In Phase II (search for and discussion of experimental solutions) two general classes of macro-topics can be found: one is relevant to the 5 kinds of simple machines, and the other one is relevant to educational activities addressed to children.

The messages dealing with the 5 kinds of simple machines mentioned in the task assignment sheet (lever, pulley, inclined plane, wedge, and screw) were divided in the following categories according to their contents (see Table 2):

- Technical (T): the object is described in its technical details; the name of each of its parts, its functions and uses are specified.
- Physical (P): the physics of the simple machine is dealt with; all the physical quantities involved and the mathematical relations which guarantee equilibrium are mentioned, either expressed in words, or expressed in formulas.
- Didactical (D): activities are proposed (most of which of experimental kind) to enable children to acquaint themselves with simple machines.
- Examples (E): examples of commonly used objects that can be traced back to models of simple machines are provided.

The incidence of messages dealing with wedges being rather low, this kind of simple machine was ruled out from the analysis and comparison.

Levers proved to be the simple machines that students most frequently identify as commonly used everyday objects. On the contrary, pulleys and screws are often described in their technical details due to their being used mostly in the technological field. Inclined plane is often dealt with in physics courses in different contexts; hence it is often described from the point of view of physics.

Table 2

	T	P	D	E	Tot. messages
Lever	13%	14%	23%	51%	44%
Wedge	25%	0%	13%	63%	5%
Pulley	47%	12%	16%	26%	26%
Inclined plane	9%	35%	17%	39%	14%
Screw	44%	17%	6%	33%	11%

The macro-topic relevant to educational activities proposed by the students definitely show that levers (88% of messages) are the most easily identifiable simple machines among commonly used everyday objects, and as such are the ones more frequently integrated into educational paths. As has been mentioned above, wedges receive no consideration, whereas screws, pulleys and inclined plane appear in 7%, 4% and 2% of messages respectively.

5.2. Transfer of the bases of physics to an educational context - Phase 3: joint design of educational paths by means of cooperative writing:

In this phase the students worked in spontaneously created groups varying from 2 to 13 students.

The *scricoll* tool for cooperative writing stores every version of the documents produced by the students thus enabling the researchers to analyse the students' work methodologies. Each student accessing the *scricoll* can either create a new document (new version) or open and edit any existing document, and save (numbered revised version).

In order to assess the extent of cooperation within each group, it is possible to analyze the personal contributions by each student and the percentage of operations performed by a student on the work done by another student.

The higher the number of students in each group, the more complex the time and relational chain connecting the revisions of the paths designed by each group.

In most cases (6 group out of 8) cooperation in versions is less than 50% (minimum percentage: 27%); only in 2 groups does it amount to 58% (group no. 7) and 61% (group no. 1). This means that students tend to open their own former versions of the path designs and to work for a limited period on materials produced by themselves. As concerns the text of each single version, a higher extent of cooperation may be remarked (fraction of modifications applied to materials formerly produced by a different author).

Small groups show the higher average number of versions per student (groups 3 and 4).

Moreover, in groups of more than 4 people there is at least one student who writes a number of versions which is at least 1.9 times as high as the average. This may suggest the spontaneous appearance of a supervisor, or of a student who works on the task during the whole time of the experiment.

The results of cooperation in the design of each path may be appreciated by analyzing the contents of the 8 educational paths designed and delivered by the students in their final version.

Firstly, it can be noticed that in most cases (7 out of 8) they are globally coherent in their contents and homogeneous in style though they have been designed by several authors. This shows that web-supported cooperation is an effective tool for teachers' training in that it does not make their design tasks heavier but, on the contrary, it favors the sharing of knowledge, competence and skills.

All of the students involved in the formation intervention start from the natural curiosity of children in order to propose activities grounded on actual experience, on learning by doing, on experiencing reality by means of all the senses. All of them propose games or practical activities as well as listening to music, fables, poems and nursery rhymes and creation of objects starting from low-cost materials. The paths are designed in such a way as to respect children's cognitive growth as well as the context of the other school activities.

However, in most cases (6 out of 8) it can be remarked that the poor scientific grounding of the authors prevents them from effective employment of physics concepts and physical quantities, from the recognition of their interdependence and of the relations occurring in the working of simple machines. This can be noticed in the following aspects which emerge from the students' works:

i) mechanical equilibrium is superficially explained by means of common sense, and in a few cases it is only referred to gravity;
ii) forces as vectors decomposable in various directions and torque to a pole are rarely dealt with;
iii) the determining role and nature of constraints are neglected;
iv) weight is treated as the force to be overcome;
v) active force is only ascribed to muscular strength.

The analysis of the 8 educational paths produced by the students led to the identification of 4 types of educational paths which are paradigmatic of the typical approach by students of the degree course in Education.

A. 4 paths out of 8 (groups 1, 3, 6, and 8) show a careful psycho-pedagogical layout, which includes quotations from Piaget, Bruner, and the constructionists Papert, Harel and Turale. The various fields of actual experience are considered, as well as the new syllabi proposed by the reform of Italian primary school, and the aims of the reform. Nevertheless, this kind of layout is not deeply grounded on the subject, which is often referred to in superficial terms. Hardly ever are scientific objectives and conceptual cruces stated and identified, or they are very similar to prerequisites.

This means that not always were the investigation of the subject and the search for connections with actual experience (performed during the first two phases of the formation intervention) matched by an in-depth study of the subject by the students.

The activities proposed in the paths produced by these groups aim at enabling children to acquaint themselves with materials (various kinds of simple machines) and terminology (lever, fulcrum, equilibrium, inclined plane, etc.) or to instruct them in the use of simple machines (mechanical advantage of simple machines) as if science learning could merely result from children's interaction with reality and not from teachers' support and guidance towards a conceptual objective. These paths are therefore lacking in systematization, correlation and modeling.

In a few cases the PEC (Prediction-Experimentation-Comparison) cycle is mentioned but this does not influence the organization of the activities.

B. A different approach can be found in the paths designed by groups 4 and 5. Here we can find a good grasp on the basic reference framework and conceptual objectives. One of the two paths contains an additional chapter to those suggested by the reference scheme dealing correctly and exhaustively with the physics underlying the equilibrium of levers.

The activities proposed by these groups highlight physical quantities and their correlation and aim at fostering children's modelling skills by means of scale construction of models with commonly used materials and of discussion of the children's observations and of experimental data.

The paths are suitable to the children's age. One of them (group 5) ranges from nursery school to the last year of primary school and goes deep into the theme of levers by means of a number of topics connected to one another in a circular approach, making a correct use of the PEC cycle. The other one (group 4) is addressed to the first year of primary school and adequately introduces the different kinds of simple machines, unlike most of the paths produced (6 out of 8) which deal only with levers.

If we compare these example with those provided in item A we can remark that they show the capability of second-year students of the degree course in Education, having a psycho-pedagogical background, to integrate scientific knowledge and professional competence provided that the conceptual contents to be dealt with are studied in depth and made clear.

C. Group 7 produced an educational path on levers, addressed to children of the fifth year of primary school. In the "Prerequisites" section we can find that some concepts are imprecisely expressed (e.g.: "children know that any motion is produced by a force"; "energy is needed so that a force can manifest its effects"; "the most common forms of energy are muscular strength and gravitational attraction") and that learning challenges are considered from a different point of view from the subject matter of the path.

Moreover, we can find that the definitions of levers, simple machines, force and equilibrium are uncritically quoted from textbooks and lesson notes. It has already been stressed that the quotation of correct definitions from textbooks reflects the students' attitude of shirking responsibilities: they do not feel the need of personal reworking and reflection upon the subject they are going to teach and confine themselves to mere quotation of statements regardless of their actual understanding of the subject.

Such an attitude may lead to teach confused or even incorrect concepts, as can be seen in the last activity proposed, in which a question asks to list the levers in a bicycle (e.g.: "brakes are levers of second order the fulcrum of which lies at the connecting point of the handlebar and the steering column"; "handlebars are levers of first order the fulcrum of which lies between power and resistance").

D. Also group 2 produced an educational path on levers addressed to children of the fifth year of primary school. This path shows a lack of integration and homogenization of the contributions provided by the group members. For instance, the introduction presents the activities as characterized by a deductive approach proceeding from the general to the particular, from theory to experience, whereas the chapter dealing with the approach presents an inductive method proceeding from an observation of reality to a discovery of rules. The activities proposed by this group are uncoordinated, juxtaposed, and have no linear time progression.

This evident failure to design an educational path is due to a lack of adequate discussion and of sharing of a common view prior to the joint design of the path, as well as to a limited view of science education which is assimilated to other subjects which can be taught through narrative.

6. Summary

The web-supported activities described in this paper were carried out in the last, network-supported, part of the training experiment which involved students from the degree courses in Education of the Universities of Udine and Reggio Emilia. The activities showed a good level of distance cooperation and brought to light several significant issues to be considered in pre-service teachers' training.

The in-depth study of the subject reveals the student's fear of assuming responsibility when discussing scientific concepts, and hence their attitude of providing either mnemonic definitions which do not develop any competence in the relevant topics, or mere description of details and avoidance of personal formulation of concepts.

As far as simple machines are concerned, students tend to describe and classify them rather than analysing them from a physical point of view, thus showing a difficulty in connecting formal learning with commonly used everyday objects.

It is also important to remark the absence of any reference to units of measurement.

The results of the search for and discussion of experimental solutions show that levers are the simple machines that students most frequently identify as commonly used everyday objects. Pulleys and screws are often described in their technical details, whereas inclined plane, which is often dealt with in physics courses, is more frequently described from the point of view of physics.

The analysis of the topics chosen by the students for the design of educational activities shows a definite preference for levers. Screws, pulleys and inclined planes are seldom mentioned, and wedges receive no consideration.

Cooperative writing provided the students with training to joint work and at the same time brought to light some paradigmatic attitudes shown by the students in the transfer of the basis of science acquired into an educational context. The most common one is that of good professional competence combined with a poor scientific grounding, which leads the students to design educational activities aimed either at merely enabling children to acquaint themselves with simple machines or at a base level application of simple machines with no closer treatment of the underlying concepts. On the other hand, in some cases, the students show a good grasp on the basic reference concepts: their educational proposals highlight physical quantities and the relations between them, and aim at favouring children's knowledge of concepts and their awareness of models.

Less frequent cases occur in which poor scientific grounding is hidden behind uncritical quotation of definitions, thus leading to convey incorrect concepts to the learners, or in which a lack of discussion within the group produces an inconsistent and badly organized educational path in which didactical issues are assimilated to narrative.

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