TEACHING SCIENCE THROUGH TECHNOLOGY AND CREATIVITY IN INNOVATIVE LEARNING ENVIRONMENTS

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Summary

The purpose of this work is to demonstrate that the critical use of technology to increase the efficacy of teaching, in particular in the field of science, is the key to single out solutions able to increase development and growth, from which, in turn, the whole society can benefit. The challenge faced by the LPS group in planning the activities for more effective and engaging science teaching, is based on the possibility to share and fill the learning needs of various categories of people, students and teachers, inhabitants of a given territory, researchers, involved in the initiative and animated by the need to find solutions to the educational problems they deal with. On a devoted learning platform, described in the contribution at length, the student's lab has been planned as a set of on-line group activities, with the general aim to provide useful elements to understand the typical characteristics of the language of science and create the structure of a creative text with a scientific topic through cooperative writing. Findings from the data collected after a specific evaluation plan are given and discussed revealing as successful the combination of creativity and science subjects.

State of the art

The *science/technology – public* relation is being reconfigured in a dialogic form. The attempt to reduce the informative asymmetries between scientists and users is related to the importance of scientific training, from a cultural and practical point of view (understanding of the function and use of technology devices in daily life), as well as from a political one (participation on the basis of conscious and well informed choices) (Thomas & Durant, 1987). Scientific and technologic culture, relevant element of the shared encyclopaedia and the individual knowledge, also becomes a tool for social and political participation. Such issue gains more importance if one takes into consideration the effects that techno-scientific knowledge reaching the mass public produce on behaviours, in terms of orientation, value-based choices, fruition capacity of the technology-related opportunities and the formation of a critical perspective. Field studies demonstrate the users' deep inability to knowingly understand and manage the technological resources, as well as a profound interference of the mediated information sources to the detriment of an objective and realistic evaluation of the access to the techno-scientific knowledge (ISTAT, 2007; Pinnelli, 2009). In light of what above mentioned, that of the dissemination of popular science is, today, a duty of public institutions as well as a right of the citizens who can, thanks to such information, actively participate in

the democratic and associative life of their own community. New technologies, in general, and the web 2.0 tools, in particular, have increased the possibilities for researchers to reach, with zero costs and in real-time, their interlocutors. At the same time, however, the risks related to the authoritativeness of the sources increased as well. If used according to the criteria of a structured reference model, technology is capable to provide room for further examination, with tools designed to represent stable architectures able to fill the cultural voids, easily detectable in today's student population, thus making the development of a responsible and impartial critical knowledge among the younger generations possible. That of technology is a culture without depth, because it is characterised by the rapidity with which the various technical solutions come one after the other on the market. In the field of didactics, there are permanents features and transitory functions. It is therefore necessary to find a coherent and effective connection system between the two dimensions. As claimed by Vertecchi (2012), the substantial difference between technological developments and tradition-related practices relies on the interpretation of time and space: a further step forward is necessary to conceive a model to which the combination technology/education can adapt. If the classic models of education are essentially about the first part of life (infancy and adolescence), it appears, today, necessary to extend this time span including adult life, for which there is no specific model of reference.

The purpose of this work is to demonstrate that the critical use of technology to increase the efficacy of didactics, in particular in the field of science, is the key to single out solutions able to increase development, from which, in turn, the whole society can benefit.

Research design and methodology

According to such premises, within the project for the creation of an *Observatory for Biodiversity* in Sicily, LPS – Roma TRE created and organised a programme of science lab activities, diversely addressed to those teachers and students who took part in the project. Such plan involved five schools in the area of Palermo (two lower level and three higher level secondary schools) with a total of 120 students and 14 teachers. The activities were carried out in a mixed modality: part in presence and part through the dedicated electronic platform, *Orbis Dictus*, developed by LPS within a former national project, FIRB (Fund for Basic Research Investments, funded by the Ministry of Education, University and Research) *am-Learning* (Adaptation of the educational message) (Vertecchi, 2011). The idea at the core of the project for science teaching comes from the need to strike the balance between different interests: not only those of the students and teachers, but also those everyone acting in the field of reference. To this end, the activities were structured in such a way that the teachers could be able to guide their students through a shared learning path. Following some introductory meetings with the LPS researchers, during which the activities and the prerogatives of the online learning environment were presented, the users could carry on autonomously on the educational path. This was divided in two modules: one for the teachers and one for the students.

The *Teaching Science* lab's objective was to provide the teachers with the theoretic and practical tools to guide their students towards a critical and aware use of the dissemination and public communication of science. The module's activities were described to the teachers through the *Orbis Dictus* (http://www.orbisdictus.it) platform. Their aim was the creation of an educational platform connected to issues in the field of biology, assigned by the platform's tutors to the end of drafting a scientific text. The idea to implement the project in a "distance learning mode" comes from the awareness that on line learning, in this case the self-teaching of the teachers, is a fundamental tool for the production and creation of knowledge: if inserted in a well-defined and structured educational path, technology can represent a valid solution for improvement. Starting from the visualization of videos whose object of analysis was Descartes' *Discourse on the method* (1637) and through guided discussions coordinated by the on line tutors, the teachers were given the chance to achieve various goals: increase their own critical thinking abilities, update on the specific characteristics of the scientific language and use such knowledge directly in the educational context, as well as increment their own competences as for the use of technologies for education. The creation of the educational unit, to be constructed following a planning approach and with the final goal of the production of a written text on a scientific topic by the students, was, for the teachers, an important chance for growth. On the other hand, autonomously, in their virtual area of reference, the students were called to reflect on the levels of complexity of some proposed texts for the transmission of contents, on the choice of language used and to be used, as well as on the modes of representation of a given content. As a first task, they were engaged in the analysis of the writing techniques of the texts on the singled out subjects, in the planning and definition of a working methodology and in the actual writing of a new learning/teaching text, in the form of a fictional story, solving the educational issues they were faced with during their work. Meta-objectives of the module dedicated to the students were singled out, such as the possibility for them not only to increase their own linguistic abilities, sometimes inadequate mainly as for the grammatical and syntactic structures, but also to increase their abilities regarding the argumentation in written form, the development of critical thinking and creativity. To this end, the students' module provided basic tools for the production and analysis of fictional (short stories, novels and screenplays) and non-fictional (newspaper articles and short essays) texts. Aspects related to creative writing were dealt with, and the basic elements and writing techniques of various genres were described, such as those of short stories and novels, cinema and television screenplays, theatre, radio, comics. The educational activities were structured so that the students could get to know and understand the world of narrative and the fundamental theories of narration, developing specific abilities. The writing module was outlined as a moment of organised and specific confrontation in a relation of stimulus, perception and internal elaboration of mental images. During the on-line lessons, students were provided with the necessary instruments to create the characters, structure the plot and avoid the most frequent narrative traps. Through practical exercises, every pupil finally gathered information to work on an outline and organically develop the narration. To sum up, the students, guided by their teachers, who were contextually engaged in the reflection on and planning of a dedicated educational unit, wrote short stories on biodiversity-related topics

and took part in an internal competition, judged by a committee created for the purpose, consisting of an educationalist, a marine biologist and a professional writer.

The challenge faced by the LPS group in planning the activities for more effective and engaging science teaching, is based on the possibility to share and fill the learning needs of various categories of people, students and teachers, inhabitants of a given territory, researchers, involved in the initiative and animated by the need to find solutions to the educational problems they deal with. As already mentioned, the outlined models and procedures attempt to answer to the necessity to involve all kinds of actors, by exploiting the potential of an aware and critical use of technology.

The following paragraph describes the peculiarities of the platform where the above activities took place.

The Orbis Dictus Platform

Over the last decades, the constant evolution of information and communication technologies (ICT) applied to teaching allowed a rapid development and an ample diversification of the technologic offer, mainly in the field of distance education. Within this new branch of research, named *Technology Enhanced Learning*, there are various tools and learning methods through new technologies, among which the creation of virtual platforms for e-learning. Numerous e-learning platforms were designed over time, constantly competing against each other, with various levels of differentiation as for the services provided. However, all those platforms employed new technologies to optimise the various aspects of the distance communication between teacher and learner, in order to make it faster, stronger, multimedia, etc. The idea at the core of the *Orbis Dictus* platform is to adapt the message to the receiver, not to force the latter to adapt to the educational content (Agrusti & Harb, 2013). In brief, firstly, it is necessary to draft a student's profile by gathering as many data as possible. Secondly, the didactic material must be adapted to the profile. The student's profile must be then newly evaluated, thus creating a virtuous circle in which the learners learn thanks to didactic materials tailored in their difficulty to their competences, or at a slightly higher level. In order to achieve such objective, a modular approach has been chosen: three software tools have been created in order to carry out each one of the three abovementioned phases in a semi-automatic way. Such software tools are able to communicate among themselves in a fully integrated system.

LexMeter

In order to plan and develop a new, innovative platform aimed at an extreme level of individualisation, the first need has been to define a profile of the verbal abilities of each student. Such profile has been identified as the preliminary condition to the following elaboration of the *individualised* messages, tailored to each student's needs. In order to carry out this activity, *LexMeter* (Agrusti, 2010) was created. Such tool allows an estimate of the number of words known to each students so to create a personalised scheme of lexical competences. In order to measure this, the software tool automatically generates tasks to be

completed, prepared not only to calculate the number of terms the student knows, but also the *typology* of said terms. Such tasks are not based on classic criteria (a word is removed every fixed number of words, or the articles, the prepositions and the linking words are eliminated). The elimination of the words is based on their frequency of appearance. In this sense, *typology* of the term means the (supposed) difficulty for a student to understand a sentence containing that given word.

Adapter

A second programme ensures the passage from the estimate of verbal competence to the adapting of the message. In other words, the idea is to move from a message aimed at a virtual receiver (the one that the creator of the text had in mind) to one more tailored on the needs of the real recipient, that is one student that distinguishes himself for a given repertoire of lexical competence. The transformation is carried out automatically by *Adapter*, that individualises the teaching message by automatically introducing textual supports (short explanations) to increase its comprehension. In other words, this software tool is used to automate the modulation of low-frequency words in the teaching message by adapting the message to the real target users (the students). The hypothesis is that the low-frequency words within the archive of texts are words difficult to understand due to their low appearance in the manuals. By integrating such words with explanatory notes it is more probable that the students can better understand the texts, thus learning more easily.

ProgressMeter

Last but not least, *ProgressMeter* has been developed. It is a programme aimed at reconstructing the learning path of each student, by noting the variations that take place in each lexical competence profile (Agrusti & Harb, 2011). Such software tool creates self-assessment tasks in order to differentiate the effort required from each student, defining, in each case, a variable interval between the virtual receiver's lexicon and the real receiver's lexicon. In other words, the programme extrapolates sentences from a text chosen by the teacher and already present in the didactic path, it highlights only the sentences containing the words from the text's glossary (the same one used by *Adapter* to adapt the texts' content) and creates a fill-in-the-gaps task by selecting five sentences in which a gap has been created by eliminating one of the words from the glossary.

Such software tools have been integrated in the applicative platform *Orbis Dictus*, a collection of programmes providing e-learning courses in order to answer the strong needs of individualisation foreseen in the educational model.

The students' activities under investigation

The student's lab has been planned as a set of on-line group activities, with the general aim to provide useful elements to understand the typical characteristics of the language of science and create the structure of a creative text with a scientific topic through cooperative writing. The objectives of the module's didactic path are outlined as follows:

- analysis of the lexicon, syntactic and grammatical structures of the examined texts;
- choice of the writing style;
- production of an original text;
- development of argumentative abilities in written production;
- development of critical thinking and creativity;
- effective use of technology.

In fact, the lab addressed the aspects related to creative writing, by providing the basic elements and techniques of various genres, with the aim of making clear to the students what the necessary knowledge for the proposed writing activities was and allowing them to get to know and understand, with specific competences, the world of narrative and the basic theories of narratology.

The didactic path within the students' lab was divided in three units, each one with its specific objectives:

1. first unit: analyse a narrative scientific text according to the elements of narratology, scientific language and creativity;

2. second unit: plan and realise the creative scientific writing through the actual writing of the end to a short story provided;

3. third unit: create, plan and realise a creative scientific text related to the themes connected to the *Observatory of* marine *Biodiversity.*

Every teaching unit was completed through group work; the activities, the works of the single groups and the time schedule were monitored by on-line tutors. Following are the themes assigned to the groups of students for the realisation of the final story: Turtle, Dolphin, Lobster, Tuna Fish, Seahorse, Octopus, Nudibranch, Pinna Nobilis, Sea Star, Shark.

Seven groups, made of 8/9 students each, accomplished all the activities foreseen and handed out a complete creative product. The short stories written by the students were evaluated by an ad hoc board to assess the achievement of the objectives foreseen within the learning path. The last activity must be regarded to as the summative task of the didactic path in the students' lab. Consequently, the evaluation of the task was deemed necessary to analyse the entire course of the didactic intervention. According to the objectives and the meta-objectives singled out within the activities and the module in general, an evaluation grid was created for the assessment of the short stories, which is presented in the dedicated content.

Analysis and findings

In order to set the evaluation of the creative short stories written by the participating students, the LPS research group moved from ideas related to the evaluation of critical thinking. The purpose of the creative feature was to support the focusing and emotional internalisation of the scientific topics that were objects of study. Paul and Elder (2012) claim that students that think critically use writing as a useful tool for communicating ideas important for learning. To elaborate a concept by writing is useful to clarify it and to acquire a higher level of precision, accuracy, relevance, depth, width, logic ability and meaning. Through writing, pupils find it easier to carry out a process of analysis and evaluation of the ideas they had while studying. Paul and Elder also state that such process can help both the learning and writing abilities, and those activities influence one another. The assessment tool created by the LPS researchers aimed, in this phase, at finding the following abilities in the products of the students' work:

- reflection;
- writing;
- analysis and synthesis;
- exemplification;
- connection of ideas;
- development of a thesis;
- understanding of the proposed scientific elements.

The assessment tool, therefore, has been structured in five sections that contain elements whose focus shifts according to the aspect object of interest. The pre-experimental character of the employment of such tool has not allowed carrying out statistical measurements on the gathered data. It allowed, however, the assessing committee (who work in different fields but were all equally involved in the kind of activity required from the students) to express a more objective judgement, coherent with the task fulfilled. The following table shows the scores assigned to the students' short stories. Each work is indicated with a letter of the alphabet in the first column on the left, while the lines contain the points given by the three members of the commission.

Table 1: Assessment for each macro-indicator by each member of the committee

|	Educationalist					Scientist					Writer					TOTAL
	Pertinence	Content	Form	Originality	Scientific language	Pertinence	Content	Form	Originality	Scientific language	Pertinence	Content	Form	Originality	Scientific language	
A	9	10	9	9	8	7	10	6	8	8	10	10	10	9	8	131
B	8	7	8	8	8	8	10	8	8	7	10	10	9	8	8	125
C	6	6	4	6	7	7	10	6	8	8	8	10	5	6	10	107
D	7	8	6	7	8	7	9	6	7	6	7	9	10	6	2	105
E	6	6	6	6	7	6	8	7	6	4	7	7	6	5	5	92
F	4	4	7	5	4	7	9	7	7	6	2	2	6	1	2	70
G	6	5	4	6	7	4	7	4	4	4	1	2	2	2	0	58
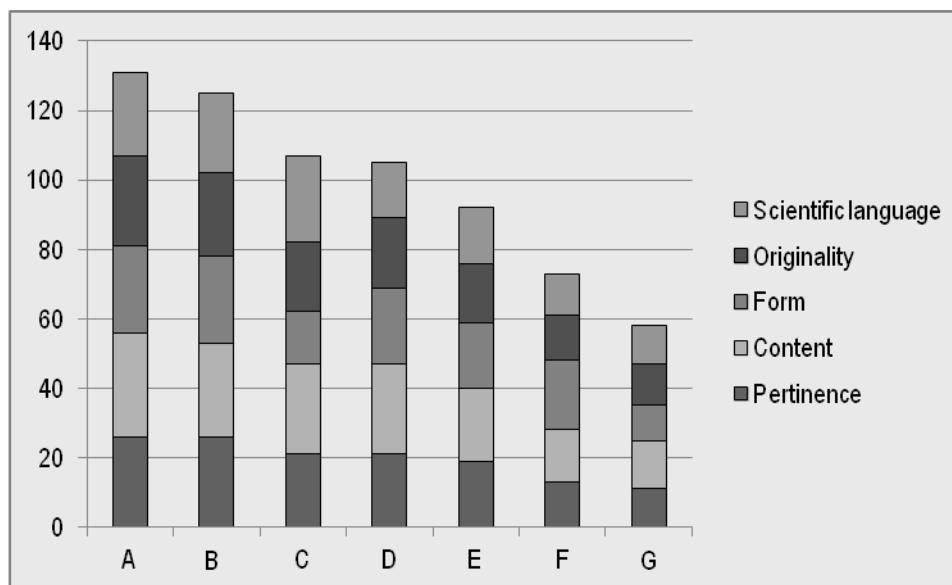
Figure 1. Bar graph of students' work evaluations

The *content* category has shown the best results: excellent and brilliant marks have been related, as previously underlined, to the ability to make use of the key elements of creative writing. The *form* and *exposition* indicator revealed, in some productions, the use of a correct and fluid speech, which also was original and strongly connotative, thanks to the use of a literary and rhetorically inspired language. In some productions the form was generally correct. Statistically minimal is the presence of punctuation and syntax errors. The *originality* category highlights good results, with peaks of excellence, in all the stories submitted. The knowledge on creative writing and the scientific topic were used in an original way and were inserted in a context that was carefully created and never banal.

Conclusive remarks and possible developments

It is useful to underline that the use of the *Orbis Dictus* platform allowed the students to work in a flexible and dynamic environment (Vertecchi et al., 2010), that supported the didactic path by providing all the necessary tools. The use of an e-learning group process, constantly supervised by the e-tutor, required strong coordination among the students, which resulted in a stronger boost by the participants in the presented activities, mainly thanks to the motivational expectations of the fellow students of the group. The cooperative learning and working mode has been, indeed, accepted since the very beginning by the students. This led to remarkable results in terms of participation and organisation of the work, as well as, as shown by the reported results, in terms of quality of the products. With reference to the tools provided, the choice to present and use in the activity short stories from the collection *Narrating Science* proved to be functional to the objectives of the LPS' group project. The students were able to confront themselves with texts written by fellow students which were characterised by the core elements of their learning path: the creative short story and the technical-scientific language. The use of such material proved to be important both in the initial phase, that in which students became acquainted with the proposed contents, and in the final one, that of the actual, written production of an original short story.

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About the Authors

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