An Interdisciplinary Environment for Science Learning

S. Cuomo[1], B. D'Aniello[1], A. Murano[*,1], and E. Saulino[2]

[1]Università degli Studi di Napoli Federico II, Facoltà di Scienze MM.FF.NN., Via Cinthia –80136 Napoli , Italy - e-mail: biagio.daniello@unina.it, salvatore.cuomo@unina.it, murano@na.infn.it

[2]ECO.FORM S.r.l - E-mail: esaulino@libero.it

In scholar curriculum, the integration of contents from different learning areas has been always a challenging issue, but with very few practical experimentations. A first attempt appears in the late 1920s under the name "core" [1]. Successively, interdisciplinary and integrated curricula have been widely associated with the progressive education movement [2]. In the last twenty years, a variety of approaches and case studies have been carried out, by combining different disciplines, pedagogical approaches, people and skills showing a deep improvement in scholar learning.
This paper describes an experimental project of integrating mathematics, natural science, and computer science (technology education) in the right curricular direction for the first level of Italian secondary school. The project is aimed to improve learning in all the above disciplines and thus overcome the low level of knowledge of them held by Italian primary level scholars, as it has been recently shown by OECD statistics [3]. We show effectiveness of the conceived interdisciplinary approach by means of case studies in a network of thirty classrooms of 11 years old scholars: the INNOVAMBIENTE project. We describe the considered arguments, including justifications and reasoning. Specifically, we describe how such an interdisciplinary study can improve upon traditional approaches to school curriculum.

Keywords Interdisciplinary Environment; Science Learning;

1. Introduction

Traditionally, Italian school curriculum has been largely based on the concept that instruction should be separated into distinct subjects, for ease of understanding, and then reassembled when complex applications are required. Such a fragmented learning approach seems less appropriate in our modern society, where everyday (often complex) innovations highly inundate the human life. On the opposite, it is well understood that combining different disciplines, pedagogical approaches, people, and skills deeply improves scholar learning. Also, present-day scholars are much more stimulated by modern multimedia teaching methods, especially when they are based on modern technologies. These concepts are even more convincing by looking at the dramatic statistics produced by the Organization for Economic Co-operation and Development (OECD) Program for International Student Assessment (PISA) 2006, specifically for the Italian country [3]. We recall that this program surveys 15-year-olds scholars in the principal industrialized countries. Every three years, starting from 2000, it assesses how far students, near to the end of compulsory education, have acquired some of the knowledge and skills essential for a full participation in society. In 2000, the OECD PISA core was literature, in 2003 mathematics, and in 2006 science. In 2006, 57 industrialized countries have been surveyed and Italian students have resulted at position 36 for science and position 38 for mathematics. These results put Italian scholars at a very low level and underline the need for innovative learning approaches for both mathematics and science. By looking at the punctual results, one can observe that the situation is even worst in South Italy. Indeed, while North and Center Italy have reached a score of 520 and 486, respectively (the average PISA 2006 score is 500), South Italian scholars have reached a dramatic score of 448. In particular, as far as the mathematics concerns, more than 50% of scholars have given wrong answers at the supplied tests.

These reasons stimulate the large use of funding, MEuro of investments, in order to equilibrate the Instruction level between Italian regions as well as between Italy and the rest of European countries. To this aim, a lot of projects have been founding by the European Union and the Italian government, such as INNOVASCUOLA. The latter, in particular, is a call for project promoted and financed by the Cabinet's Department for Innovation and Technology (DIT) with the collaboration of Ministry of Education, Universities and Research (MIUR) [4]. It belongs to a series of initiatives for the promotion and integration of the use of new technologies in teaching. INNOVASCUOLA intends to offer to all schools in Italy, of all orders and degrees, the opportunities given by the ICT. The objectives of the initiative are:

- to facilitate the introduction of innovative didactic methods for teachers and students;
- to trigger a virtuous innovation process starting from inside the schools themselves, favoring the

[*]Corresponding author: e-mail: murano@na.infn.it, Phone: +39 81 679279

expressiveness of teachers and students allowing them to develop and share digital contents, offering new opportunities to the market, both encouraging traditional editors to make their know-how more visible, as well as stimulating the participation of multimedia sector operators.

The first call under the INNOVASCUOLA initiative came out last June, to whom we have applied with an experimental project called INNOVAMBIENTE. This project is aimed to integrate mathematics, natural science, and computer science (technology education), in the right curricular direction for the first level of Italian secondary school. In particular, we have focused our attention on South Italy schools, because they suffer more of the “early school leavers” problem, and because of the lower instruction level of their scholars, as discussed above. The project has been accepted for founding in a very selective review process (only 327 projects over 1000 have been accepted) and judged as one of the most outstanding projects in the Campania Region (6th position).

The rest of the paper is organized as follows. In section 2, we describe the project INNOVAMBIENTE. Section 3 describes two case studies and shows how the interdisciplinary teaching improves upon traditional approach. Finally, Section 4 gives some conclusions.

2. The INNOVAMBIENTE Project

2.1 Overview

INNOVAMBIENTE is devoted to 11 years old scholars of Italian secondary school. We have named the project INNOVAMBIENTE as we have taken the opportunity, under the Italian call for proposal INNOVASCUOLA, to experiment an innovative learning approach for the natural environment education through a combined application of mathematics and computer science notions. We have chosen to focus on the natural environment since this theme is nowadays considered of particular relevance, especially for the Southern part of Italy, where this project is addressed.

The project started in September 2008 and will hold for two years. It involves a network of 30 classrooms, each one with an average of 20 students and 3 teachers. The project is organized in more phases where natural science is integrated with mathematics and computer science by following the Italian Ministry Educational programs. Each phase is focused on experiments and the use of new technology tools in order to learn the disciplines involved. Although mathematics and computer science are first introduced as accompanying teaching tools, they are going to be deeply studied as well. The intent is to give students, at the end of the whole learning process, the feeling that these accompanying disciplines have been learned “for free”. This shows that the choice of correlating natural science with mathematics and computer science is not casual at all and, as we also show in the next section via practical case studies, it really helps teachers in their work, as well as students in the learning process. We have considered the integration of the three disciplines in such a way that the base knowledge of each of them could converge in a single subject, focusing on the same problem, but without losing their own identity.

2.2. Goals and Methodology

INNOVAMBIENTE desires to help teachers understanding that their specific educational areas do not stand alone within the school curriculum and that, by combining them, students can have benefits in learning each of them. The methodological approach is mainly based on practical experiments. In practice, teachers prepare very simple scientific experiments that, under their guide, scholars can easily reproduce inside the classroom and the school laboratories. Moreover, most of the experiments are thought to be realized in the biggest natural laboratory always available and open all the time: the natural environment.

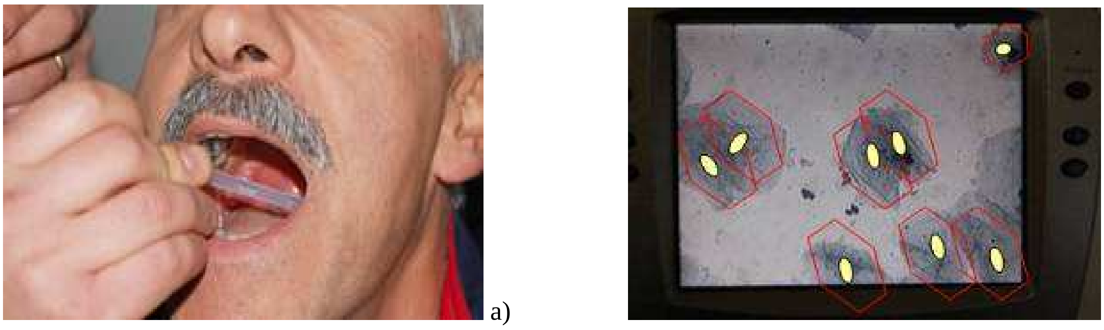
This interdisciplinary teaching approach intends to attract students much more than the classical ones. First, it helps students to become more conscious regarding the natural environment in which they live and of which they are an integrating part. Second, students take benefits from the immediate application of mathematical concepts, which are often perceived as a very abstract topic, as they do not see any immediate applicability of them. Also, the use of mathematics to real problems enlightens the property that this discipline is directly oriented to "problem solving". Third, the application of computer science techniques and tools to realistic problems helps students to learn and increase their abilities on multimedia and data evaluators tools. Like for the mathematics, computer science is often thought in school as a very abstract topic, using ad-hoc invented problems to solve. Such problems miss the most important step of a computer science application: the certification that what has been realized at the end of the process is exactly what was required at the beginning [5]. With the application of computer science to real problems, students can instead test the appropriateness of the used tools, the efficacy of the implemented reports, storages, multimedia representation, etc. Finally, students are naturally accompanied to organize the logical aspects of each experiment roadmap in terms of a simple algorithm, with the intent to introduce the classroom to the basic aspects of the computer programming.

3. A case study and results

In this section, we focus on how to combine in a very attractive way (from students' point of view) natural science, mathematics and computer science, in a common subject of study. In particular, we are less interested in examining the empirical evidence about whether or not the interdisciplinary study “works”, since there is a huge amount of research in literature of this sort [6]. Within the INNOVAMBIENTE project, we have elaborated a set of lessons regarding different topics related to cell theory, water analysis, reproduction and biodiversity. Here, for the sake of space, we only report two experiment proposals, which are respectively introduced to show effectiveness of the interdisciplinary study inside the school and outside, in the natural environment.

3.1 Case A: Cell Theory Lesson

The experiment starts by picking human cells from the internal cheek of a voluntary teacher. The mucosa cells are weakly connected and can take away without any pain with a light scraping, via a pipette (Fig. 1a).



a) b)

Fig. 1 a) Picking of human cells with a pipette and b) cells with hexagonal approximation.

The pipette is successively smeared on a glass were the cells naturally adhere and colored with methylene blue. Then, the glass is mounted for observation on a microscope where cells appear light blue (Fig. 2). Starting from the acquired image, we observe that the figure has a geometrical structure. The cells in the figure may be "approximate" with hexagons. For simplicity, suppose that they are regular (Fig. 2).

Let **l** and **a** be respectively the side and the apothegm of each single cell-hexagon, by defining its perimeter (**p**) and Area (**A**) to be equal to:

$$\mathbf{p = 6 * l \text{ and } A = a * p / 2.}$$

The teacher can ask students to calculate the total area occupied by all cells on the glass. He can also pose new problems: Observe microscopically the cells and their size in (μm), assuming we can measure the side of the regular polygon; what size should have the nucleus? Regarding computer science, first consider that the above experiment is reproduced on an interactive white-board connected to the microscope by an USB camera. To let students better understanding the developed geometry concepts, teachers also use interactive software for Euclidean geometry such as Cabri Geomtrie (Fig. 2). Then, students use spreadsheets to collect all data and develop counting results. Finally, a multimedia representation will help to reproduce the basic step of the experiment, with the possibility to serf it for deepening.

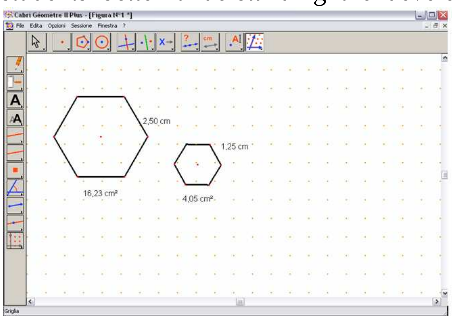


Fig 2: Hexagons with Cabrì Geometrie.

In conclusion with this experiment, students are able to experimentally study the feature of animal cells, the basic Euclidean notions of plane figures, its software graphical representation via geometrical software, few basic computer science tools for collecting data and virtually reproduce the experiment and show the obtained results.

3.2 Case B: Lepidoptera Biodiversity

This experiment starts in the landscape and manly considers butterflies as bio-indicators [7]. By following a fixed path in a protected natural area of the

Mediterranean Maquis, students count all butterflies they can see within a ray of 300 metres, and repeat the counting several times. They may also catch some samples, recognize them following a book guide, and then quickly release them. Successively, students repeat the same experiment in an unprotected environment, but with similar vegetation, and compare the obtained data with those from the protected area. Scholars enumerate all different butterfly species observed by alphabetical letters. To the aim of clarifying the experiment, assume that overall 8 different species have been observed during the experiment (see Fig. 3).

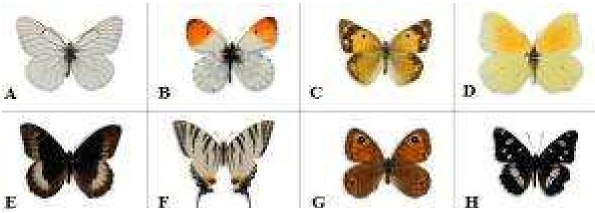


Fig 3: Butterfly species

At this stage, students are invited to create a mathematical model of the realized experiment for a better representation, organization, and evaluation of the obtained data. In particular, the mathematical model has to help students to come out with a relationship between data and results. This is usually obtained by using the concept of *function* that in the specific example returns from the input data, the butterfly species, a number that corresponds to a Biodiversity index [8]. Therefore, the aim of this procedure is, from one side, to simplify the Biodiversity concept in such a way it becomes easily understandable by the young scholars and, from the other side, to give scholars a real application on which experiment arithmetic theories.

Coming back to our example, suppose that students have collected the following data in the natural (**N**) and unprotected (**U**) environment, with respect to Fig. 3:

1. Aporia crataegi (N=7, U=0)
2. Antocharis cardamines (N=12, U=3)
3. Colias Crocea (N=20, U=32)
4. Gonepteryx cleopatra (N=4, U=1)
5. Hipparchia fagi (N=3, U=0)
6. Iphiclides podalirius (N=5, U=1)
7. Lasiommata maera (N=10, U=2)
8. Limenitis reducta (N=7, U=0)

Therefore, the data of the considered problem are the different species of butterflies observed (8 for N, and 5 for U) and their overall number (68 for N and 39 for U). Said p_i, for i to be one among A...H, the number of samples recorded, for each specie, we have:

- p_A: 7/68 for N and 0/39 for U (species A);
- p_B: 12/68 for N and 3/39 for U (species B);
- p_C: 20/68 for N and 32/39 for U (species C);
- p_D: 4/68 for N and 1/39 for U (species D);
- p_E: 3/68 for N and 0/39 for U (species E);
- p_F: 5/68 for N and 1/39 for U (species F);
- p_G: 10/68 for N and 2/39 for U (species G);
- p_H: 7/68 for N and 0/39 for U (species H).

Students can now calculate the Simpson's index [8]:

$$\mathbf{D= p_A * p_A + p_B * p_B + ... + p_H * p_H.}$$

They obtain, respectively for N and U, the values D_N= 0.01384 and D_U= 0,0254 and, as it was expected, both numbers are between 0 and 1. Hence, students understand the biodiversity concept directly from the experiment they have performed: *“the more the obtained index is close to zero the more diverse and heterogeneous is the considered ecosystems (and vice-versa)”*. Therefore they logically conclude that the unprotected environment is, with respect to this measure, less heterogeneous than the natural one.

Both the input and output data of the experiment are successively organized by students via databases (for the data storage) and multimedia tools (for the visualization and analysis of the results). Regarding the former, students use spreadsheets and are introduced to basic DBMSs concepts, from which they can query data about a specific butterfly species and therefore make a report from it. About the latter, scholars can experiment the integration of media contents, in particular images and videos, and therefore the production of a digital didactic unit (CDD). In fact, this is one of the main goals of INNOVASCUOLA.

So, what do the scholars learn from the whole interdisciplinary learning process? They learn how to study the environment, through the Biodiversity analysis. Moreover, with such an experiment, they are "kindly forced" to use both arithmetic and computer science concepts, in a very simple way, so that they can improve their knowledge in both disciplines.

4. Conclusion

In the current science educational system, students are often considered either a success or a failure, with a worrying superficiality [9]. We believe that the main problems related to learning scientific disciplines derive from the fact that students take passively the information that the teacher supplies them. For students that have good ability of abstraction, this naturally assures the reachability of the prefixed targets, but for students that are much better in practical activities, such an approach surely takes into failure. Such a strategy, thus, does not support a (often considerable) part of the classroom. A valid solution to these problems is based on the exploration of alternatives learning methods. In particular, teachers have to facilitate every scholar to make such an exploration by itself [10]. The INNOVAMBIENTE project is aimed to pursue such a goal. Hence, it experiments an innovative learning approach where scholars can acquire new knowledge through experiments, in such a way that they can collect information from tangible surrounding data. Therefore, starting from natural science, every experiment immerses students into mathematical theories, in the management of the electronic data acquired, and in the reproduction of the experiment via multimedia tools. Also, the application of mathematics to real experiments allows to eliminate the annoying problem that scholars often perceive this discipline as a set of isolated notions, far away from the reality and therefore with very few applications. Moreover, the application of computer science to real problems allow students to certify that what they realize is exactly what is required to solve the problem, which is instead usually missed while solving classical toy-problems taken in the classroom[5].

Following the INNOVAMBIENTE project, a student becomes the main actor of its education. Since he needs to face time by time new problems, he will be induced to develop and refine its intuitive abilities. In this way, teachers can use in a better way the students "emotional intelligence", which is the ability of motivating the student to pursue a target in spite of frustrations [11]. Moreover, by working on data produced personally, a scholar will be much more motivated to learning and deepening knowledge.

Finally, we point out that some of the interdisciplinary INNOVAMBIENTE lessons have been also carried out (and completed) by the same authors of this paper in a small network of 3 classrooms of 9-years old scholars. In that case, students have been very enthusiastic about experiments. Evaluation tests have successively shown that all students have completely acquired the rudiments of the mathematical theory behind the experiments. Also, tests have certified the acquired ability from the students to synthesize the experiments, store data, elaborate graphics, and represent a whole experiment with the obtained results in a multimedia presentation, as a unique subject (CDD).

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