Application to the Informatics Europe Best Practice Award 2016

ALaDDIN
Computer Science Department
Università degli Studi di Milano, Italy

1 Introduction

In the Italian schools, most of the cultural impact behind informatics is neglected, since this fertile scientific discipline is often blurred by the use of office automation tools or Internet communication facilities. For the latter meaning we coined the term 'applimatics' in order to wipe out any ambiguity: in fact, although such activities might indeed need special skills, they can be presented and mastered without referring to computing at all.

To cope with this troublesome state of things, in 2008 we founded the ALaDDIN working group ("Aladdin: LAboratorio di Divulgazione e Didattica dell'INformatica", `http://aladdin.di.unimi.it`), aimed at changing the way informatics is taught and perceived, with special attention to K-12 non-vocational schools.

All the activities we developed in these six years focus on two key goals.

1. *To popularize the scientific aspects of informatics,* by distinguishing them clearly from the use of informatic tools and devices: with this intent, we started a game contest (Kangourou of Informatics [18, 19], `http://kangourou.di.unimi.it`) aimed at distributing to pupils and teachers of secondary schools (grades 6th to 13th) rigorous but engaging materials about the scientific aspects of informatics; in 2012 we joined the Bebras community (`http://bebras.org/`) and the Kangourou of Informatics adopted the approach of its 'International Contest on Informatics and Computer Fluency' (2015 IEPBA winner). Since 2009, about 23'000 pupils have partecipated to the contest and we have distributed about 13'000 booklets ([1, 22, 21, 16, 17, 14, 15]) with commented solutions to the proposed games. Since 2015 we adopted the Bebras formula without entry fees (`http://bebras.it`): it allowed us to reach more than 12'000 pupils from all the regions of Italy in just one edition; commented solutions are now distributed by our contest system (`http://bebras.it/students`).

2. To teach the basics of informatics starting from low grades: to this end, in 2010 we started devising some activities aimed at presenting and discussing the core of informatics as the *"automatic processing of information"*. Planning to expose to informatics pupils of different ages, generally not involved in a computing curriculum and without previous specific knowledge, we developed an approach based on playful activities which imply a mix of tangible and abstract object manipulations: a strategy which we call 'algomotricity' [4, 7, 20]. The computer is never a starting point, but all activities end with a computer-based phase in which participants use specific software tools that we have developed. After experimenting with different formats, we consolidated five two-hour workshops, which we have proposed to about 2'400 students between 2011 and today. Since 2011 we are also engaged in the training and continuing education of teachers; in particular, we had the opportunity to propose a methodology based on the algomotricity approach to about 500 educators. In particular, in the last year we started a pilot project with Sardinian Region to introduce programming to the teachers of the local schools (from primary to upper secondary) and we were in charge of the training of two groups with a total of 45 teachers.

We are firmly convinced of the importance of exposing all pupils to basic informatics concepts and believe that our unconventional approach is indeed successful in presenting informatics both as an attractive scientific discipline and as a fundamental formative subject. We already applied for the 2015 Best Practices in Education Award and we got a honorable mention. We would like to apply again for the 2016 Best Practices in Education Award since we believe the award can contribute significantly to further developing our activities and expanding the audience to which they are proposed.

2 Names and addresses of the applicants

- *Carlo Bellettini*, Associate professor.
- *Violetta Lonati*, Assistant professor.
- *Dario Malchiodi*, Associate professor.
- *Mattia Monga*, Associate professor.
- *Anna Morpurgo*, Assistant professor.
- *Massimo Santini*, Assistant professor.

Computer Science Dept., Università degli Studi di Milano, Via Comelico 39, I 20135 Milan, Italy (`aladdin@di.unimi.it`).

2.1 Indication of whether the submission is on behalf of an individual or a group

We apply on behalf of the ALaDDIN team ("Aladdin: LAboratorio di Divulgazione e Didattica dell'INformatica", `http://aladdin.di.unimi.it`).

3 Description of the achievements (max 5 pages)

Our goal is to present informatics as an attractive scientific discipline and expose to it pupils of different ages, not necessarily involved in a computing curriculum or with a previous knowledge of information or programming. To this end we developed an approach in which abstract symbolic manipulation is partially replaced by physical activities that should help pupils in developing their mental representations: a strategy which we call *algomotricity* [23, 4, 5, 6, 7, 20].

3.1 Methodological roots

As the name suggests (the neologism is a portmanteau combining *algorithm* and *motoric*), algomotricity exploits kinesthetic learning activities [2], with a first phase in which pupils are informally exposed to a specific informatic topic, followed by an abstract learning phase devoted to let students build their mental models of the topic under investigation and a final computer-based phase to close the loop with their previous acquaintance with applications, in order to match at least in part the expectations of pupils, who often identify informatics with the use of a computer. In this last phase pupils are confronted with specially conceived software tools and exploit what they have learned during previous phases.

Our approach took inspiration from several papers in computer science education (for example [8, 9, 24, 3]), and it is clearly rooted on the *Experiential Learning Theory* (ELT), specifically on *Problem based learning* (PBL). ELT defines learning as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience. [...] Immediate or concrete experiences are the basis for observations and reflections, these reflections are assimilated and distilled into abstract concepts from which new implications for action can be drawn. These implications can be actively tested and serve as guides in creating new experiences" [13]. PBL designs an educational environment based on experiential learning organized around the investigation, explanation, and resolution of meaningful problems.

In our workshops, as advocated by PBL, students work in small collaborative groups and learn what they need to know in order to solve a problem [12]. The conductors of the workshops help pupils toward the learning goal without forcing them to follow a specific path; rather, the teacher should be able to exploit unexpected events to point out relevant issues not necessarily foreseen in the original design. This requires a trade-off between free exploring and external constraints: the didactic environment should suitably limit the available degrees of freedom so that pupils can effectively and proficiently explore the

Grade	4^{th}–8^{th}	7^{th}–11^{th}	10^{th}–13^{th}
information	Wikipasta	Human Pixels	Human Pixels (advanced)
automation	Mazes	Mazes (advanced)	Clickomania
processing			Greedy Money & Scheduling

Table 1: Proposed workshops

Figure 1: Pictures taken during the workshops: Wikipasta, Human Pixels, and Mazes.

solutions' space without either getting lost or having the feeling that there is only one *right* answer. A key part is that pupils should have a real possibility to *make mistakes, i.e.,* to explore strategies that give incorrect or sub-optimal results. Since pupils are asked to work in groups in all steps of the activities, they confront and exchange knowledge and skills one with each other.

3.2 Sketch of workshops

Table 1 summarizes the proposed workshops and the relative target grades.

Each activity was designed to focus on one fundamental concept:

information What is information? How can symbols/numbers be used to represent it?

processing How can information be manipulated/changed in order to produce new knowledge?

automation Which manipulations can be performed by a *mechanical* interpreter? How can this be done?

3.3 Short description of the workshops

We propose several workshops (see `http://aladdin.di.unimi.it/laboratori.html`, Figure 1 show some pictures taken during the workshops), the most popular ones are the following:

Wikipasta In this workshop pupils are posed the problem of describing the typographic aspect of a text. By playing with pieces of pasta and other small objects, they are led through a game to the discovery of mark-up languages and then introduced to a lightweight "wiki" syntax. The final activity on the computer is about editing Wikipedia-like pages.

Human pixels After being shown a video of animations made in stadiums by coordinated soccer teams supporters (so called "human LCD"), pupils are asked to discuss how to set up a very simplified version of such animations using only two colors (e.g. black and white). They eventually discover grids, sampling, resolution, compression and complete the activity by using a multi-view editor showing a picture along with different representations as a matrix of numbers. In the advanced version of the workshop pupils use a set of colored, transparent tiles to be stacked onto a bidimensional grid in order to reproduce simple images, being faced with the problem of color quantization.

Mazes In this workshop pupils are faced with the problem of guiding someone through a simple maze. Pupils first focus on the task of verbally guiding a *human robot* (a blindfolded mate) through a simple path. Initially they are allowed to freely interact with the robot, then they are requested to propose a very limited set of primitives and to compose them into a program to be executed by the robot, with the possibility of exploiting three basic control structures (if, repeat-until, repeat-n-times). After this, pupils are provided with a visual programming language (a simplified version of MIT Scratch) and are asked to write programs guiding a sprite through mazes of increasing complexity. The advanced version of the workshop uses more complex paths and mazes in the first and second part of the activity, respectively, also introducing pupils to the concept of *variable*.

Greedy Money In this workshop pupils work on greedy strategies. They have to write down an algorithm for an automatic change dispenser, after having played with money on the change-making problem with a set of coins that admits a greedy solution. Then they are guided to apply the same strategy to a scheduling problem and, by playing with an ad hoc software tool, evaluate its suitability in finding the optimal solution.

Clickomania This workshop focuses on arrays, loops, and variables for counting. The final task of the workshop is the implementation of a program to play (a simplified version of) "Clickomania" (also known as Chain Shot! or Same Game) or, more precisely, a program that updates the board after each player's move (click). Here the software tool (`http://click-aladdinunimi.rhcloud.com/`) is an application based on Blockly [11], a web-based visual block programming editor. Initially pupils have to tackle the problem of how to update a single column. They first focus on the task by playing with multicolor pegs by simulating the effect of moves on a pegboard, then they are requested to formally describe their procedure, and finally to implement it with Blockly.

More detailed English descriptions are available in [7, 6, 20].

We try to introduce a new workshop each year. In 2016 we did a pilot experiment with a new workshop designed for 8th graders where the active observation of recursive algorithms execution allows them to understand the main features of a recursive process, to persuade themselves that it works in order to unveil the mystery of its effectiveness.

It starts with an unplugged algomotorial activity with LEGO blocks where an algorithm is executed by pupils, it continues with an activity supported by a software tool we developed ad-hoc, and is concluded by the abstract consolidation of the basic concepts and properties which come out during previous steps.

4 Evidence of availability of the curricula materials to the teaching community (max 2 pages)

We are disseminating our approach to teachers in multiple ways. Since 2011 our group is involved in several activities devoted to the initial training of prospective computer science teachers for the upper-secondary school, as well as in the continuing education of (also non computer science) secondary school teachers. Such activities have been delivered in various forms: two-hour workshops for the continuing education of teachers (`http://aladdin.di.unimi.it/formazione.html`), specific semester-based classes for the initial training of teachers (`https://mameli.docenti.di.unimi.it/A042`), and an elective class on Informatics teaching devoted both to computer science master students and to secondary school teachers (`https://mameli.docenti.di.unimi.it/didainfo`). Moreover, in 2015 we started a pilot project with the Sardinian Region to introduce programming to the teachers of the local schools (from primary to upper secondary, `https://mameli.docenti.di.unimi.it/digitiscol`) Despite such diversity, all activities have been focused on (i) introducing teachers to the workshops described in Sect. 3, and (ii) analyze them in depth with the aim of enabling participants to autonomously and efficiently reproduce the workshops in their classes. To this end, the web sites contain all the material needed for the workshops.

It is worth noting that the algomotorial activities in the first part of each workshop require inexpensive materials (for instance paper clips, pasta, sticky notes, tiles or other material which can be easily created with paper and scissors) and that the software tools we designed for the final part of the workshops are freely available from our web site `http://aladdin.di.unimi.it/materiali.html`.

5 Evidence of impact (max 5 pages)

A main impact of the activities described in this document is the number of participants to the proposed laboratories.

2011: 200 students (Ist. Marie Curie (Garda))

2012: 582 students (matematita centre)

2013: 466 students (matematita centre)

2014: 767 students (matematita centre and Ist. Ilaria Alpi (Milano))

2015: 481 students (matematita centre and Ist. Maria Ausiliatrice (Lecco))

2016: 486 students (matematita centre and Ist. Villoresi)

As far as training and continuing education of teachers is concerned, the number of participants to our courses have been:

Education of prospective teachers (TFA/PAS)

- abilitation courses for Informatics teachers for secondary schools (2013, 2014, and 2015: around 40 participants).

Continuing education of teachers

- Workshops for secondary school teachers held during the Kangourou of informatics contests (between 2011 and 2015: 123 participants)
- Refresher courses for primary and secondary school teachers held at the Museo Nazionale della Scienza e della Tecnologia 'Leonardo da Vinci' (2014: 60 participants) and in the Bolzano IV institute (BZ) (2014: 50 participants)
- Continuing education project '#Digit-Iscol@' with the Sardinian Region to introduce programming to the teachers of the local schools (from primary to upper secondary) (2016: 45 participants)

Elective course on Teaching of Informatics

- we started on the 2014/15 academic year and the first two editions of the course had around 20 (5 school teachers) and 15 (2 school teachers) participants, respectively. In both cases we had the opportunity to work with a mixed class: computer science master students and secondary school teachers who have enrolled just to attend this single course.

5.1 Evaluation

During the academic year 2014/15 we set up an assessment process which involved 150 pupils and their teachers. The pupils were attending the same suburban state school, who promoted the participation of all its 6th- and 7th-grade classes to two of our workshops: Mazes and Wikipasta. Each of the pupils filled out the questionnaires: currently we have examined and analyzed all the questionnaires (see Sect. 5.1.1) about Mazes (proposed to the 6th-grade classes), in the spirit of grounded theory [10]. Moreover, we organized a focus group (see Sect. 5.1.2) with representative pupils from most of such classes. We collected:

- field notes written during the observation of some classes taking part in the workshop;
- questionnaires filled out by pupils;
- three focus groups with pupils;
- interviews with some teachers.

5.1.1 Questionnaires

Pupils were asked to answer three open questions: 1. What did you like of the workshop? 2. What didn't you like of the workshop? 3. Is there something you feel you have discovered during the workshop? We analyzed the answers and identified some recurring themes and strong concepts. Pupils claim to like: the fact that the workshop is both amusing and complicated/clever/challenging/engaging, and the fact they have created/built something; moreover, they feel they have discovered:

- the importance of thinking/designing/figuring in one mind's what to do before doing it;
- the need for precision;
- that computers and other automatic devices do not work alone, but follow commands;
- that computer science is not only using computers;
- that informatics is a science;
- that informatics may be fun.

It is worth noticing that such concepts emerged from all classes quite uniformly, thus they can be considered well-representative of the content and methodology of our proposal, and not depending on the different conductors or tutors who carried out the workshops.

5.1.2 Focus groups

We proposed as discussion topics the main themes and concepts arising from the previous analysis. In order to activate the discussion, some selected sentences from the questionnaires were handed out and read aloud with the participants.

During the discussion most themes were recognized by all the participants. Everybody agreed on the importance of precision to avoid errors and/or risks for the robot, both during the execution of instructions, and when defining the instructions themselves (*e.g.,* how many steps, which turning angle). We registered a unanimous agreement also on the need for reasoning before doing; in the discussions pupils repeatedly used verbs like *thinking, processing, preparing, foreseeing, understanding, solving, schematizing, agreeing*; or terms like *problem* and *logic*; or expressions like *organizing, ordering, putting together*, referred to both *ideas* and *instructions.*

Pupils confirmed that the tasks they had to carry out were fun and difficult at the same time, and stressed the fact that the challenge was part of the amusement, because "solving complex tasks is rewarding". However, when asked whether tackling with complex tasks is always amusing, they all clearly gave a negative answer ("I'm willing to use my brain, if the situation is enjoyable."), and pointed out that in this case the activities were fun per se. Words like *playing* or *game* were used to describe the activities, but someone felt such terms too reductive: "it was not child's play", "it was educational".

Another topic proposed during the discussion is the perceived relationship between the workshop and the subjects taught in school. The concept of *precision* was immediately associated with technical drawing and mathematics; geometry was associated with the measure of length (number of steps of the robots) and turn angles. No spontaneous reference to science emerged. After the moderator suggested some hints, however, all pupils easily associated what happened during the workshop with the typical *observation-hypothesis-prediction-testing-analysis cycle* of the *scientific method*, and in particular with the concept of *experiment*. They reported several circumstances in which they had made a hypothesis (for instance about how many steps were needed), designed a program/experiment, executed/tested it, and verified the correctness of their hypothesis. They also recalled that, when the experiment failed, they reviewed the hypothesis according to its outcome, and started the process anew: "the robot went too far, let's try with fewer steps!" And "when something goes wrong, you often discover something new that you didn't imagine before" (*e.g.,* one is concerned about the number of steps, but finds out that also the the turn angle is wrong). Such an approach was also used to choose among ideas proposed by different members of a group: some were tried and failed, while other survived to the experiment and were accepted in the final solution.

5.1.3 Final observations

The focus group showed that the activities proposed were effective in thoroughly engaging the pupils in the work. Moreover it also highlighted that some important educational values were conveyed with the workshops. The first one was precision, often felt by pupils as an unnecessary requirement imposed by teachers but with little sense for the pupils. Here they had to recognize the necessity of precision and appreciated it as an important value, not as an inappropriate constraint. Then they admitted that they tend to be unwilling to make efforts in the things they study at school, but realized that when they are involved in something fun, they are happy to accept challenges and work and think hard, and even reason before doing. Finally, the activities are designed with the scientific method in mind and pupils actually observed, made hypothesis, verified them in the context of the activity, possibly reviewed them, and eventually built mental models (theories) and recognized having worked in this way.

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6 Letters of support

We enclose three letters of support.

The first one is from Sandra Ennas ('Sardegna Ricerche', `http://www.sardegnaricerche.it/en/`) who supervised our contribution to the `#Digit-Iscol@` project, funded by the Sardinian local government.

The second one is from prof. Simonetta Di Sieno, the Director of the Interuniversity Research Center for the Communication and Informal Learning of Mathematics (`http://www.matematita.it/presentazione/index.php?NL=en`). This center hosts most of the lab activities we organize.

The third one is from prof. Micaela Francisetti, Principal of the state school in Milan in which we organized the workshop evaluation reported in this document ('Ilaria Alpi' institute, Milan, `http://www.icilariaalpi.gov.it/`), and prof. Martina Palazzolo, the math and science teacher responsible for locally coordinating the activities.

The second and third letters were written for the 2015 application.