Problem Solving Olympics: an inclusive education model for learning Informatics

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ISSEP 2018

Problem Solving Olympics

- Problem Solving Olympics (*OPS*) were launched in 2008 on the initiative of Italian Ministry of Education, University and Research
- Main goals
  - improve general problem solving aptitude
  - introduce computational thinking

Problem Solving Olympics

- Trans-disciplinary approach to captivate teachers of various disciplines
  - OPS are offered as contests to engage students
  - however, no real successful participation is possible without support and training from teachers
  - teachers should develop and promote curiosity, interest and consensus in their own classes
  - teachers should therefore be actively involved in the game even if they (initially) lack skills and competences needed

Problem Solving and Computational Thinking

- Computational thinking is a powerful tool to solve problems
- Computational thinking is often *defined* as a form of problem solving
- Problem solving can be used as an engaging opportunity for active learning of computational thinking

Problem Solving Olympics

- *Olimpiad* or *Olympics* in education usually (in Italy) indicates
  - competition
  - for individuals
  - to promote excellence
  - among grade 11 or 12 students

Problem Solving Olympics

- OPS are
  - ~~competition~~ learning activities
  - ~~for individuals~~
  - ~~to promote excellence~~
  - ~~among grade 11 or 12 students~~

Problem Solving Olympics

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  - ~~for individuals~~ for teams (4 players per team)
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  - ~~among grade 11 or 12 students~~

Problem Solving Olympics

- OPS are
  - ~~competition~~ learning activities
  - ~~for individuals~~ for teams (4 players per team)
  - ~~to promote excellence~~ to reach every student
  - ~~among grade 11 or 12 students~~ in the whole range of compulsory education

OPS Competitions

- Coding / Programming Competition: students engage with creative programming activities, realizing a project on a topic chosen by the OPS committee
- Making Competition: students realize a physical project using electronic boards (e.g. Arduino) on a topic chosen by the OPS committee
- *Classic* Problem Solving Competition: students try to solve a set of given problems in a fixed time frame
- The rest of the talk is about the latter

Structure and Organization

- Each edition offers a set of series of contests spanning an entire school year
- Last editions
  - 3 team contest series (grades 4-5; grades 6-8; grades 9-10)
  - 2 individual contest series (grades 6-8; grades 9-10)
- Each series
  - starts with several *training contests* (usually 4)
  - followed by 2 *competitive* (selective) contests
  - difficulty of the problems tends to increase from one context to the next one

Structure and Organization

- In each contest pupils are given a list of problems and are asked to solve as many as possible in a well-defined time frame
- Usual time frame: 120 minutes for training contests, 90 minutes for competitive ones
- In team contests quantity and hardness of problems are chosen so that the amount of work to solve them largely exceeds the effort that can be expected from a single participant in order to foster team-working, planning of activities, collaboration

Problems

- Most of the given problems can be tackled with informatics methods or techniques
- Some of them are pure informatics problems
- Some topics strongly connected with informatics
    - paths in a maze or in a chessboard
    - knapsack
    - hierarchies
    - graph covering and traversal
    - cryptography
    - search of subsequences
    - reading/tracing of procedures written in a pseudo-code
- A semi-formal syntax about terms, lists, strings is employed in the formulation of many problems and also to report solutions

Problems

- After each contest, commented solutions to all problems are provided
- Often this section makes up an outline for the in-depth study and analysis that teachers are invited to follow along with the students. In this way, knowledge and skills are spread among teachers and students
- For difficult problems, the comments are longer and elaborate

Problems

- Example 1

In a deposit of minerals there are samples of various weight and value identified by acronyms. Each sample is described by an abbreviation containing the following information:

$$\textbf{tab}(< \textit{mineral code} >, < \textit{value in euro} >, < \textit{weight in kg} >)$$

The deposit contains the following minerals: $\textbf{tab}(m_1, 13, 20)$, $\textbf{tab}(m_2, 15, 12)$ $\textbf{tab}(m_3, 22, 17)$, $\textbf{tab}(m_4, 8, 32)$, $\textbf{tab}(m_5, 11, 24)$.

Having a small truck with a maximum capacity of 61 kg, find the list L of the codes of three different minerals that can be transported simultaneously with this vehicle and that have the maximum overall value; also calculate this value V.
N.B. Sort the list increasing lexicographic order; for the abbreviations used, we have the following order: $m_1 < m_2 < m_3 < \dots$

Problems

- Example 2

  Dom, Freda and Angel need to paint a fence. Dom could paint the entire fence in 5 hours, Freda in 10 hours and Angel in 7. How much time do they need if they work together? Put the number H of hours and the number M of minutes (eventually rounded) in the box below as an integer number.

Problems

- Example 3

The technical office of a small town must choose where to place new street lamps. The town can be thought of as a set of squares connected by roads, described by the following graph (where the nodes are the squares and the arches are the streets): **arc**(n_2, n_5), **arc**(n_4, n_2), **arc**(n_3, n_6), **arc**(n_4, n_6), **arc**(n_6, n_1), **arc**(n_1, n_2), **arc**(n_5, n_1)
Each street lamp illuminates the square in which it is located, the streets that come out of it, and the squares directly connected to the square where the street lamp is located. The mayor, to save money, wants to use the least possible number of street lamps, but at the same time wants to present to the city council several possibilities to choose from.
Please find:

1. The minimum number N of lamps necessary to illuminate all roads
2. The K number of possible ways to illuminate all the roads with N street lamps
3. The list L of N street lamps that illuminates all the streets and does not include the square n_5

Problems

- Example 4

Determine the output value of the following procedure:

```
procedure BETA;
variables B, I integer;
variables A(1:4) vector of integer; A := [3,1,4,2];
I := 1;
B := 0;
while I < 5 do;
    B := B + A(I);
    I := I + 1;
endwhile;
output B;
endprocedure;
```

Production Process

- The problems are prepared by means of a controlled process
- Involves two (sub-)committees
  - the problem editors define the problems and write texts and commented solutions
  - the problem reviewers check for errors and difficulty
- Strict time schedule
  - for each series, one context every 4 weeks
  - results of a context guide the calibration of the difficulty level of the following context in the series

Teaching Strategy

- Problem-based learning of computational thinking competences
- Use semi-formal setting and pseudo language to embed problem solving in the context of computational thinking with the perspective of (eventually) acquiring programming skills

Teaching Strategy

- OPS favor incremental learning by offering series of contests, of increasing difficulty, spanning an entire school year
- Soon after the end of a contest, commented solutions to problems are made available, as training materials for the following contest

Teaching Strategy

- Teachers are encouraged to help the students to prepare for the contests
- Problems often have connections to school subjects, to encourage the inclusion of OPS training in curriculum activities
- Long-term goals of teachers involvement
  - teachers also acquire and consolidate computational thinking skills
  - teachers start using such skills in their everyday teaching

Teaching Strategy

- Within a series of contests, several *recurring problems* are present
- Recurring problems are basically different instances of a same, more general, problem
- No explicit teaching of general algorithms, contestants are naturally fostered to discover (even by internet search) one
- Some problem solutions require the execution of (easy) calculations to be repeated a number of times so large to make the solution infeasible unless one writes and executes a program

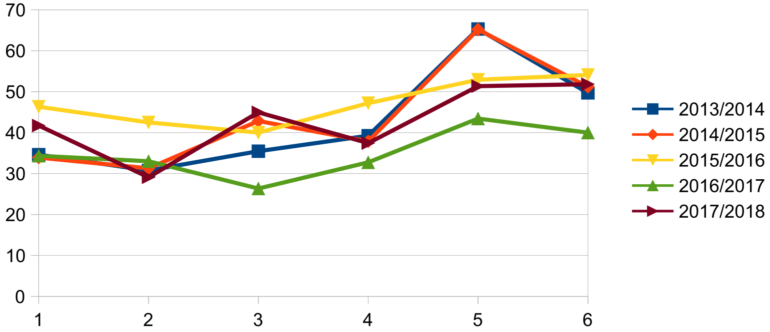
Preliminary Data

Participation to the first 10 editions of the OPS

School Year	Number of Rounds	Teachers	Students
2008/2009	3	550	10200
2009/2010	5	500	9850
2010/2011	6	400	7400
2011/2012	6	630	11400
2012/2013	4	880	16500
2013/2014	6	400	15100
2014/2015	7	500	12000
2015/2016	6	830	16700
2016/2017	6	850	23357
2017/2018	6	730	22225

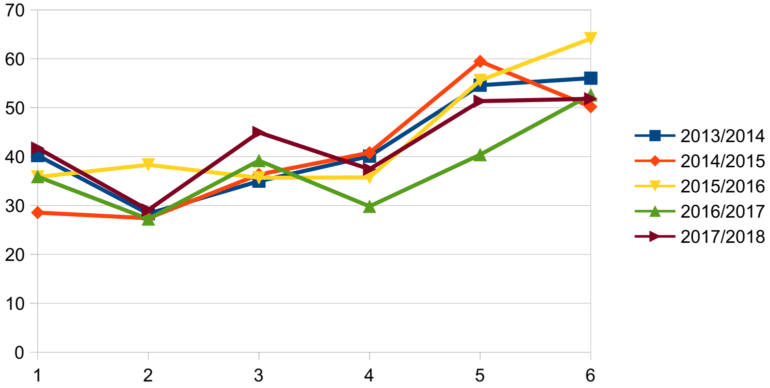
Preliminary Data

Average score in algorithmic problems for grades 4-5



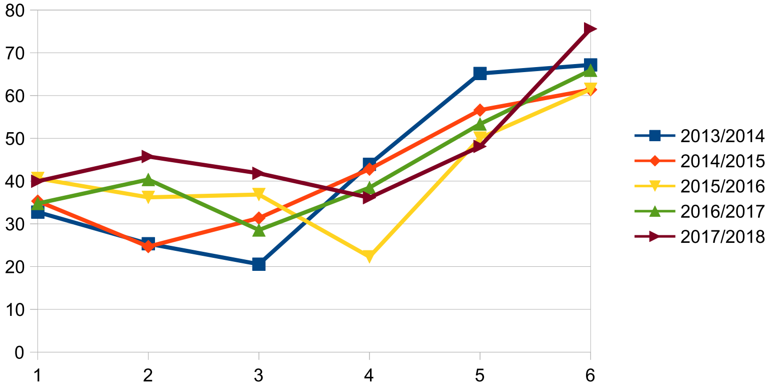
Preliminary Data

Average score in algorithmic problems for grades 6-8



Preliminary Data

Average score in algorithmic problems for grades 9-10



Conclusions

- OPS is a growing initiative to disseminate computational thinking in compulsory education in Italy
- Main features
  - problem-based learning
  - collaborative work inside the group and with teachers
  - active participation
  - challenge versus duties
  - motivation for the students to explore their own topics to support the challenges
- Plans for research work
  - OPS and gender
  - learning evaluation of computational thinking and problem solving skills
  - explore correlation between participation to OPS and general performance of students (as measured in standard tests, like PISA)