# A Platform for the Italian Bebras

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Abstract: The Bebras International Challenge on Informatics and Computational Thinking is a contest open to pupils of all school levels (from primary up to upper secondary) based on tasks rooted on core informatics concepts, yet independent of specific previous knowledge such as for instance that acquired during curricular activities. This paper describes the design choices, the architecture, and the main features of the web-based platform used to carry out the Italian Bebras contest. This platform includes functionalities needed by students, teachers, and Bebras staff during the execution of the challenge, tools to support the preparation of tasks and the training of students, instruments to evaluate the results and analyse data collected during the challenge. The platform is online since 2015 and it has managed the participation of around 25,000 teams and a significant amount of training sessions.

## 1 INTRODUCTION

The Bebras International Challenge on Informatics and Computational Thinking (The Bebras Community, 2017) is a yearly contest organized in several countries since 2004 (Dagienė, 2010; Haberman et al., 2011), with almost two million participants worldwide. The contest, open to pupils of all school levels (from primary up to upper secondary), is based on tasks rooted on core informatics concepts, yet independent of specific previous knowledge such as for instance that acquired during curricular activities.

The tasks are designed by the Bebras community, which includes the representatives of more than 50 countries. The community organizes an international workshop yearly, which is devoted to proposing a pool of tasks to be used by national organizers in order to set up the local contests. The national organizers then translate and possibly adapt the tasks to their specific educational context or to their specific way to propose tasks to the schools of their country. For instance, the French edition is based on interactive versions of the tasks, and pupils can repeatedly submit answers until they achieve a correct solution. Participation is individual in some countries and team-based in other ones; in some school systems the participation to the Bebras is compulsory. In any case tasks should stimulate an entertaining learning experience, thus they should be moderately challenging and solvable in a relatively short time: the community guidelines suggest three minutes on average. Unfortunately, however, it is not easy to predict the difficulty of tasks (van der Vegt, 2013; Bellettini et al., 2015; Lonati et al., 2017b). The difficulty of tasks is indeed a critical aspect of the challenge, as it is not easy to predict, but crucial for the challenge's success. Research on task difficulty in general, and on Bebras tasks in particular, is on going and data collection for studying difficulties is one of our goals.

Besides being used during contests, Bebras tasks are more and more used as the starting points for educational activities carried out by single teachers (Dagienė and Sentance, 2016; Lonati et al., 2017a; Lonati et al., 2017c). Bebras tasks were also used to measure improvements of students' attitude to computational thinking (Straw et al., 2017).

In Italy (ALaDDIn, 2017) the Bebras Challenge is proposed to five categories of pupils, from primary ($4^{th}$ grade and up) to secondary schools, who participate in teams of at most four pupils. The setting described in this paper has been used since 2015; from 2009 to 2015 the Italian Bebras was managed by a different organization who operated through a Moodle-based system, now offline (Cartelli, 2009),



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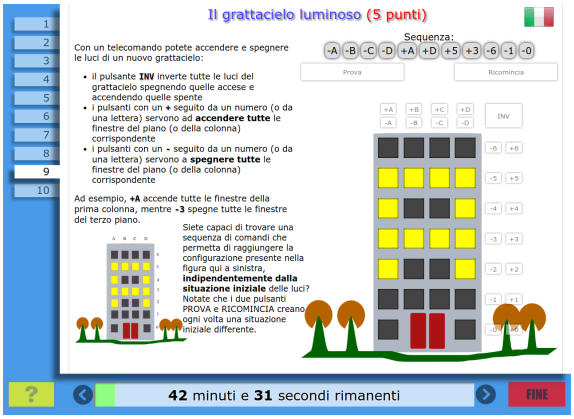


Figure 1: A typical task.

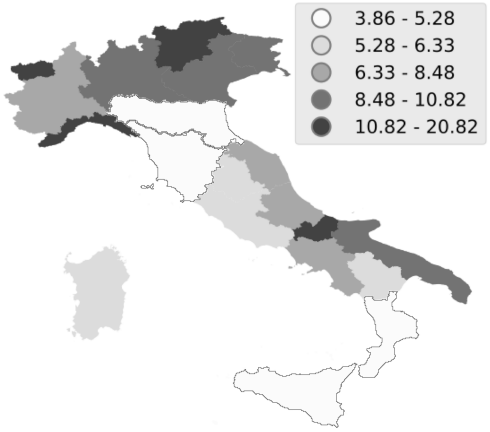


Figure 2: Bebras popularity in the Italian schools; the color of each administrative region denotes the permillage of pupils participating to the Bebras w.r.t. the total population in school age (source of school data: National Institute for Statistics (ISTAT), 2014).

and a similar contest (the "Italian Kangourou of Informatics", see below) was held in parallel: the two started to collaborate and eventually merged into the current Bebras Challenge. The contest now takes place in schools during the *Bebras week* (usually at mid November): under the supervision of teachers, teams access a web application that presents the tasks to be solved. Differently from some of the other countries, in Italy normally only few tasks are based on multiple-choice questions; most of them are *sophisticated* tasks, in that they present open answer questions, they are interactive, or they require complex, combined answers (Boyle and Hutchison, 2009). Consistently, sometimes partial scores are contemplated and there are no penalties for wrong answers.

An example of interactive task is presented in Figure 1. The task has buttons which represent switches that selectively turn on or off rows or columns of a skyscraper's lights. The task's request is to write a sequence of switch operations to get the light picture shown in the small skyscraper on the bottom left of the task, whatever the current state of the windows, which changes at every trial and is in fact unpredictable.

The 2017 edition saw the participation of 12,214 teams (about 45,000 pupils, corresponding to around 7 pupils every thousand who are attending an Italian school, see Figure 2); the teams partook to the Bebras during the week November 13–17, each category had 10 tasks to be solved within 45 minutes, for a total contest time of 50 hours across the week.

Before 2015, we organized a contest similar to Bebras named "Italian Kangourou of Informatics" (Lissoni et al., 2008). It had two rounds, the first one having the same format as the present Italian Bebras Challenge, which in fact at first inherited some of the tools already used for Kangourou. However, the increasing number of participants and the evolution of technologies (the previous system was available as an application based on Macromedia Flash and working only on MS Windows) induced us to redesign and implement a brand new system which supports all the phases of the competition (before, during and after the contest takes place) and that can be used on any platform with a recent web browser; this paper describes the design choices, its architecture, and main features conceived to cope with Italian Bebras peculiarities.

The paper is organized as follows. In Section 2 we present the general features of the platform and its architecture. In Section 3 we discuss in particular the components of the system that are in use during the contest, and the underlying design choices. Section 4 illustrates the life cycle of tasks which includes editing, administration, evaluation, and analysis of collected tracking data. In Section 5 we survey tools used to manage Bebras competitions in other countries and finally in Section 6 we draw some conclusions.

## 2 PLATFORM DESIGN

The Italian Bebras platform supports all the phases of the competition.

**Before the contest:** organizers prepare the tasks; teachers sign up in the platform, register teams and edit information about the school and the team members (age, gender, optionally the names); guests can try the tasks proposed in previous editions of the contest and get immediate feedback about their score;

**During the Bebras week:** teams access the tasks and submit their answers; organizers and teachers can monitor the situation of teams;

**After the contest:** task answers are evaluated; collected data are analyzed by organizers; teams can display tasks together with the answers they submitted, (one of) the correct solution(s), an explanation and some hints for further in-depth study in a *"It's informatics"* section, and the number of points achieved for each task; teachers can display the total scores of all their teams and print attendance certificates containing the name of the team and other optional information like the names of team members, the team's scores, the global ranking.

Some aspects of the Italian situation we have to deal with must be pointed out. The software, hardware, and network ecosystem in Italian schools is rather varied. Although we recommend to schools to use a recent version of one of two popular web browsers (Mozilla Firefox and Google Chrome), the devices on which our Bebras platform is used are very different with respect to form factors (several schools use tablets), performances, and way of administering. For example, during the 2016 edition we saw connections from several different operating systems: MS Windows 32bit (88.5%), GNU/Linux on Intel 32bit (2.8%), GNU/Linux on Intel 64bit (2.4%), MS Windows 64bit (2.2%), Linux on ARM (2.1%), and others (iPad, BlackBerry, . . . ). Hardware is often old and poorly managed: it is common to have unsynchronized system clocks or misconfigured locales. Moreover, very few schools have a reliable Internet connection: we cannot assume the network is available during the whole contest or even only when the allocated time expires. All these issues have been considered in the design of the Italian Bebras platform.

In the following we will use the following terms: a *taskset* is an ordered collection of tasks that are proposed to some category at some Bebras edition; whenever a team accesses the platform and downloads a taskset, a *test* is instantiated, which gathers all information concerning the taskset (and hence the included tasks) and the team, together with answers and tracking data. Hence, for each team there should be exactly one (running or concluded) test, and for each taskset there are as many tests as the number of participants for the corresponding category.

Figure 3 sketches the general architecture of the Italian Bebras platform.

The system manages different kinds of data: *Tasks and Tasksets* contains all information about categories and tasks, including texts, images, and code for animation and interaction; *Correction code* defines how tasks have to be graded; *Answers & Tracking Data* are collected during the contest and include both the submitted answers and other tracking data such as switch time among tasks or editing of previously inserted answers; *Teacher & Team Data* contain all information about teams (*e.g.,* members' name, age and gender), schools and referring teachers.

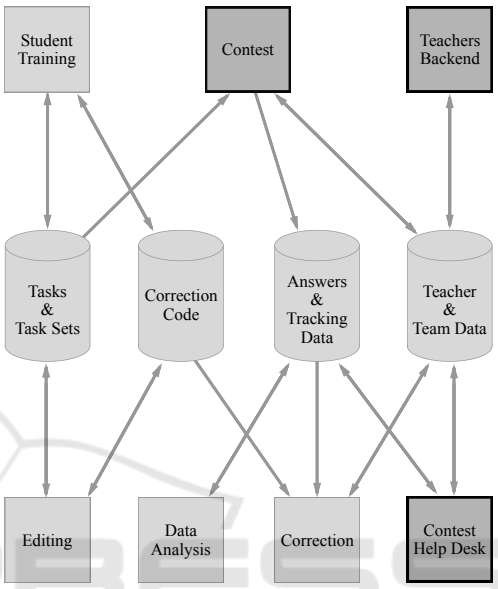


Figure 3: The architecture of the server.

In the upper part of the figure there are the access points designed to be used by contestants: *Contest* is the main front end used by students to participate to the contest; *Teacher backend* is used by teachers to create, manage and monitor their teams; *Student training* is used by students to look at and try tasks from the previous contests.

In the lower part there are the access points designed to be used by the Bebras staff: *Editing* is used to collaboratively edit and code tasks, explanations and solutions; *Correction* evaluates answers after submission and assigns scores accordingly; *Data Analysis* performs statistical elaboration starting from collected tracking data; *Contest Help Desk* is used during the contest to monitor its evolution, detect problems that may arise, manage teachers' help requests.

The darker nodes in the figure are the access points that are active during the contest; they will be discussed in the following section.

# 3 DURING THE CONTEST

## 3.1 Contest

The Italian Bebras is delivered via HTTPS: during the Bebras week, each team connects to a website containing the HTML/CSS/Javascript for tasks (ten in the 2017 edition) and tries to solve them within a 45 minutes time limit.

To avoid a webpage look-and-feel and provide instead a videogame-like layout, tasks are prepared so that each of them takes up exactly the space available in the whole screen, independently of the device, browser, or screen resolution used. A little space is saved for the left navigation bar that allows teams to switch among tasks, and the bottom navigation bar, which shows the remaining time and provides buttons to open the help page and to exit submitting the answers. A screenshot of an interactive task is shown in Figure 1.

The contest scenario, described in the previous section, introduces several important problems to be solved at a design level. The main problem is probably the unreliable nature of the Internet connection available in many schools. In particular this becomes critical when coupled to the strict time constraint for solving the tasks. The first design choice is that all needed resources (*e.g.,* JSON with tasks' definitions, images, and so on) need to be successfully downloaded before the start of the test, so that the operations of browsing and solving tasks become independent of the network. The browser's Local Storage mechanism (W3C, 2016) is used in order to guarantee persistence of data not only during the normal operations of the test but also in case of computer's crashes. When a team finishes its test or at the expiration of the available time, the system stops the interaction with the tasks and tries to connect to the server in order to send the answers. This operation has no timeout and in general can be retried also after a switch off-on of the computers, even in a following day. In some cases however this solution is not feasible, because administration policies of the school labs may enforce a total reset of all caches, cookies, and local storage of the browser at each switch on of the computers.

## 3.2 Help Desk

During the contest week, a phone helpline is available to all the teachers, and Bebras staff members are connected to the help desk site to monitor the advancement status of tests. Due to the design restrictions described in the previous section, the visible status information are limited to: start of a test (with all information regarding school, referring teacher, starting time), end of a test (with information about used time, submitted answers and statistical data).

These *simple* pieces of information permit the staff to individuate several anomalous situations: more than one access by a single team, out-of-time tests (*e.g.,* time has expired but no answers have been submitted due to network problems or errors in the closing procedure), prematurely closed tests (especially for primary school level, some teams wrongly terminate the tests instead of passing to the next task).

In each of these situations the help desk staff compiles a ticket, contacts the referring teacher, and if needed operates on the server status to reset anomalies. Teachers are guided in the operation to be accomplished on the client (for example resubmitting the answers if not correctly done the first time).

## 3.3 Teacher Backend

Teams are enrolled to the Bebras challenge by their teachers, who need first to sign up to the system. The backend allows them to create teams by specifying their name and category and by editing the data about the team members.

During and at the end of the contest, teachers can edit team data, for instance to rearrange teams in case of absentees. They can also monitor their teams by looking at a global table, and check whether their answers have been correctly submitted to the Bebras server. When something unexpected occurs (see the cases mentioned in the section concerning Help desk), they are notified via the backend and they can possibly contact the help desk staff.

After the end of the contest week, answers are evaluated and scores and placements appear within the team table in the teacher backend.

Attendance certificates can be then produced as PDF files and printed via the teacher backend. Each certificate includes the name of the team, the school, and the name of the supervising teacher; other data can be optionally included team-wise, like the names of team members, the gained score, or the overall placement (given in terms of percentiles). Such option is given in order to not stress the competitive aspect of the Bebras challenge: indeed teachers usually decide to make high placements public and avoid highlighting low results. Certificates for supervising teachers are also available.

More than a teacher from the same school may enroll teams and, if they agree, the system allows teachers from the same school to share information about their teams. Not requiring a unique referring teacher distributes the work load among several peo-

ple and permits to give credit to the many teachers in a school who engage their classes in the Bebras challenge by training teams and/or supervising them during the contest. Thus the enrollment of teams is fostered, which increases the overall number of participants.

# 4 LIFE CYCLE OF A TASK

We illustrate the functionalities of the platform by presenting the development phases of the tasks that are included in the Italian contest.

1. The tasks are conceived by a member of the Bebras community, they are revised by other members, and they are finalized during the annual International Bebras Task Workshop.
2. A set of tasks is selected, adapted and translated into Italian; in particular some kind of animation, interaction or feedback is planned for most of the tasks.
3. Each selected task text is collaboratively edited and inserted into the Bebras platform; the editing covers also the explanation and the *"It's informatics"* texts, and the coding of the interactive component of the tasks.
4. During the contest, teams access the platform to display the tasks and insert answers; when the time expires, answers are submitted to the server together with tracking data.
5. After the contest, answers are automatically evaluated and scores are assigned to teams; the logics to evaluate answers and assign scores is usually implemented before the contest.
6. After the contest week, students can look at their score, display tasks, and compare the answers they submitted with the proposed correct solution and related comments.
7. Answers and tracking data are analyzed in order to study perceived difficulties, preferred tasks, differences among age levels, and other relevant issues.

Such phases are discussed in the following section, where the task in Figure 1 is used as leading example.

## 4.1 Task Editing

The platform provides a multilanguage (BBCode, Markdown, HTML) editor with live preview which allows the Bebras staff to collaboratively edit and code tasks, explanations and solutions. In particular it enables the staff to prepare and adjust the layout of tasks, create and edit texts, make tables, provide the JSON code for the interactive parts and the Javascript code to check the answers, this all directly within the platform, so that each update on a task is immediately available to everybody.

Figure 4 depicts the Skyscraper task in editing mode: the layout of the task is shown and it is possible to click on each part to modify it, with respect both to its layout and its content. In this figure the interactive part was clicked on and the pop-up menu shows the object type and allows one to select what to view and edit, in this case its JSON and the code associated with it. After selection of an option, a full size editor window pops up, which closes after saving, uncovering the updated task.

By clicking outside the layout rectangles, a different menu pops up with options to access and edit the "checking program" and "explain and answer" (that is the explanation and *"It's informatics"*) parts of the task.

Figure 5 shows the code windows for the skyscraper task. It is possible to modify it and to test it on a given answer.

Each Bebras task must have an explanation about how to solve it and an *"It's informatics"* part which illustrates the informatics concepts on which the task is based. In the platform these two parts belong together with the task. When accessing this part, the editor opens a two-pane window, the top pane for the source code, the bottom pane providing a live preview (see Figure 7).

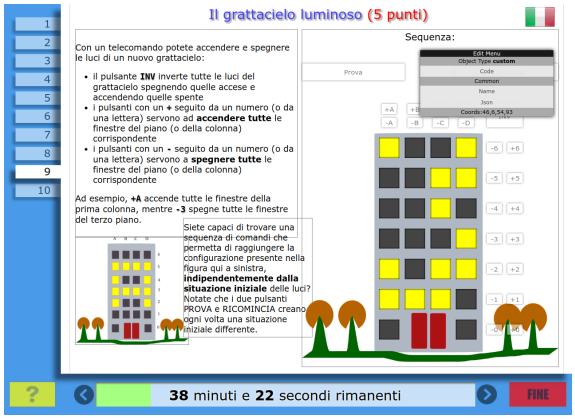


Figure 4: A task in editing mode: the layout of the different parts.

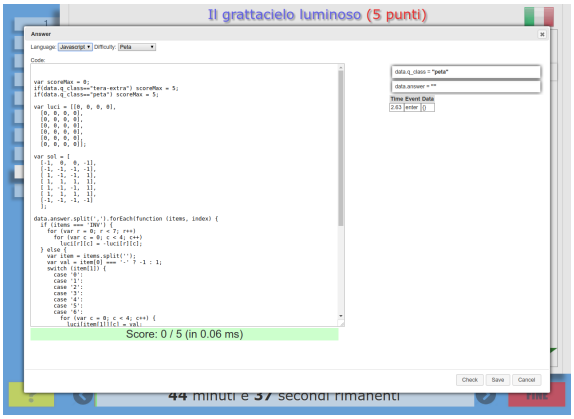


Figure 5: A task in editing mode: the answer's checking code.

| Time | Event | Data |
|---|---|---|
| 2.63 | enter | {} |
| 26.65 | change | {"key":"answer","value":"-A"} |
| 30.48 | change | {"key":"answer","value":"-A,-C"} |
| 31.42 | change | {"key":"answer","value":"-A,-C,-B"} |
| 32.19 | change | {"key":"answer","value":"-A,-C,-B,-D"} |
| 34.96 | change | {"key":"answer","value":"-A,-C,-B,-D,+5"} |
| 36.74 | change | {"key":"answer","value":"-A,-C,-B,-D,+5,+3"} |
| 38.7 | change | {"key":"answer","value":"-A,-C,-B,-D,+5,+3,+A"} |
| 39.75 | change | {"key":"answer","value":"-A,-C,-B,-D,+5,+3,+A,+D"} |
| 41.11 | change | {"key":"answer","value":"-A,-C,-B,-D,+5,+3,+A,+D,-6"} |
| 43.22 | change | {"key":"answer","value":"-A,-C,-B,-D,+5,+3,+A,+D,-6,-0"} |
| 43.9 | change | {"key":"answer","value":"-A,-C,-B,-D,+5,+3,+A,+D,-6,-0,-1"} |
| 46.47 | leave | {} |
| 54.05 | enter | {} |
| 54.92 | leave | {} |
| 55.86 | enter | {} |
| 56.77 | leave | {} |
| 57.93 | enter | {} |
| 60.26 | change | {"key":"answer","value":"-A,-C,-B,-D,+5,+3,+A,+D,-6,-0,-1,+6"} |
| 61.34 | change | {"key":"answer","value":"-A,-C,-B,-D,+5,+3,+A,+D,-6,-0,-1,+6,-6"} |
| 62.8 | change | {"key":"answer","value":"-A,-C,-B,-D,+5,+3,+A,+D,-6,-0,-1,+6,-6,+1"} |
| 63.69 | change | {"key":"answer","value":"-A,-C,-B,-D,+5,+3,+A,+D,-6,-0,-1,+6,-6,+1,-1"} |

Figure 6: Tracking data about the accesses to the task and modifications to the answer.

## 4.2 Correction

Another important component of the system is the part devoted to the correction of the tests. The design solution takes into account several requirements: in order to guarantee the fairness of the contest no correction/solution hint must be available on the student client during the contest; on the contrary during training sessions the correction could be accomplished client side; the answer verification and score attribution should potentially consider several factors like partial solutions, category of the solver (the same task could be offered to different categories but the score is proportional to the relative difficulty), number of trials or time used.

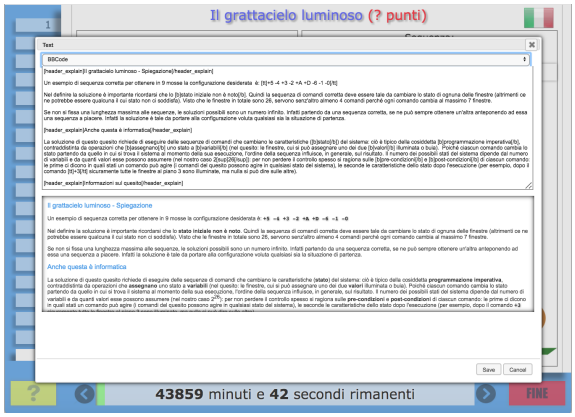


Figure 7: A task in editing mode: the explanation and "It's informatics" parts.

The task editor makes possible (see Figure 5) to write a Javascript function returning a pair of integers corresponding to the actual and maximum score of the task. The system makes the context of the task (category, runtime and answer data) available to the function.

The Javascript language has been chosen as the preferred language (the system permits to use also Python and PHP) because of the possibility to easily execute it on the client during offline training.

## 4.3 Data Analysis

In order to better understand and reason on contest results, a significant amount of data is tracked during the contest.

Time of events (*e.g.,* entering and exiting a task, clicking on buttons, changing text-area values) and values of changed fields are directly available as raw data (see Figure 6).

These data permit us to calculate interesting metrics: total time spent on a task, time dedicated to the reading of a task before the first interaction, time spent before deciding to skip a task, successive revision of an answer even after exploring other tasks.

Such data is processed to discover statistical anomalies or other clues of cheating behaviours. We recall that the contest is a non competitive challenge, but identifying these situations is needed in order to obtain clean and reliable statistical data.

Moreover, we use them to analyze the students behaviour and better understand what attracts their attention and effort, by looking at how they peruse the tasks.

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# 5 RELATED WORKS

Most of the countries involved in Bebras have their own Contest Management System, often developed by the organizing group.

(Kristan et al., 2014) describes the Slovenian system, used also in Serbia. It is based on Yii (a PHP web framework, see (Yii Software LLC, 2017)) and it supports multiple choice answers and interactive tasks, properly written in HTML/CSS/Javascript. They also provide a task preparation system based on Django (a Python web framework, see (Django Software Foundation, 2017)) that can be used to create customized contests. The three-tier architecture of the Slovenian system is specially designed to be scalable and fault tolerant: it should be able to cope with a parallel participation of dozens of thousands of participants. They consider several levels of administrative roles in order to manage all the life cycle of the contest: system, country, coordinators, and mentors. Persistence of data is provided by MySQL databases (Oracle Corporation, 2017).

France has a highly modular system (France-IOI, 2017) used both in Bebras and Algorea (an advanced contest focused on algorithms). They have the largest user base and their system is highly scalable on on-demand cloud computing platforms like Amazon web services (Amazon.com, 2017). They also provide the review system used by the Bebras community to setup the annual workshop. The French system is implemented in PHP and tasks are to be manually written in HTML/CSS/Javascript, possibly using their own predefined libraries for common task types.

(Dagienė et al., 2017a; Dagienė et al., 2017b) describe the Lithuanian system. This system is also based on a three-tier architecture implemented in MySQL, PHP and AngularJS (Google, 2017), a Javascript web application framework. Tasks are encoded using HTML/CSS/Javascript and can be authored with the "Bebras lodge" editor, a separate system used also for achiving tasks. The contest management system provides the ability to export tasks in the SCORM format (Advanced Distributed Learning, 2017), a popular standard used by many e-learning platforms.

# 6 CONCLUSIONS

This paper presented the web-based platform supporting the Italian edition of the Bebras challenge, which is used by participants and organizers before, during and after the contest. The platform core has been online for the last three years, managing the participation of around 25,000 teams, as well as a significant amount of training sessions. The platform is a key asset for the Italian Bebras, it enables the management of a contest involving thousands of students with a very lean operational staff: five academics and one professional programmer who collaborate in their spare time, and 500 hours of helpdesk support mainly delegated to junior collaborators.

Several features have been added during its three years of activity, which can be summarized as follows: tasks access is web based, but the system is quite robust since it keeps working even with poor or intermittent Internet connections, which are quite common in Italian schools, and allows one to recover data in case of client crashes; tasks can be displayed from a browser running on a variety of different devices, spanning from computers with low-resolution old screens to last-generation tablets and smartphones; when rendered each task occupies exactly the size of the screen, independently of the used device, so that the contestants' experience is more similar to videogaming than web browsing; besides data about team members and submitted answers, during the contest several other data are tracked that concern the interactions of users with the platform, thus enabling a thorough analysis of results, also in light of a better assessment of the difficulty of each task (Bellettini et al., 2015; Lonati et al., 2017b); management of teams by teachers is integrated within the platform; help desk tools are available to monitor the contest and support teachers whenever problems arise; finally, all the information related to a given task (*i.e.,* text, images, and code for animation/interaction/feedback and for automatic evaluation) is embedded into a JSON encoding, thus allowing the possibility of exporting tasks.

We plan to extend further the analyses of tracking data, in order to better understand how students engage with tasks. Moreover, we want to exploit the modularity of our platform to implement another component of the Bebras platform, that will enable teachers and students to make use of the tasks beyond the contest, for instance by accessing tasks individually out of specific tasksets, exporting them in printable forms, or creating personal tasksets. We hope this will foster the use of tasks in curricular activities, as educational resources to learn informatics and computational thinking.

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