Behind the Scenes of the Italian Coding League: Online Experience-based Training for Computer Science Students

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Abstract. During the pandemics, the need to switch to the online setting gave us the opportunity to involve a group of university students in the design and realization of an online coding challenge among middle school classes: the first edition of the Italian Coding League (ICL). The second edition of the Coding League took place in March 2022 and involved 609 students from 29 classes from 9 Italian regions. In the paper we present the format adopted for the organization of the ICL competition (an online game realized on a multiplayer game platform - one class, one player) and then focus on experiential learning process adopted for university students involved in the initiative. Finally, we present an assessment of the entire activity using data collected during the competition: we decided to refer to a public and scientifically recognized framework to define the challenges to be included in the competition and this allowed us to have explicit metrics useful to identify the degree of skills and competences exercised during the competition by the players.
Keywords: Experience-based Learning; Online Educational Games; Computer Science Education; Empowering Soft Skills; Near-mentorship Practices Innovative

1 Introduction

Experiential learning is quite common in Computer Science degrees in the form of capstone projects [1,2] related to programming or data science. In this paper, we present an activity proposed as part of an introductory bachelor course on Computer Science Education, named ICDD (Computer Science for Creativity, Teaching, and Dissemination). The learning outcomes of the course include skills to design and conduct hands-on lab activities for introducing beginners to coding and programming. These hands-on activities are targeted to primary and middle school students and their contents are based on the national directions for teaching Computer Science in schools, proposed by the CINI (Italian Inter-university Consortium for Computer Science) [3]. In pre-pandemic times, our students acquired such skills through design and conduction of in-presence laboratories mainly based on block-based visual languages, such as Scratch [4] and Pocket Code [5]. The need to switch to the online setting gave us the opportunity to introduce an additional gamification element [6,7], by involving our students in the design and realization of an online coding challenge among middle school classes, named Italian Coding League (ICL). ICL, jointly organized by the Digital School Interest Group of the University of Genova and by Edutainment Formula, took place in March 2022 and involved 609 students from 29 classes from 9 Italian regions. (The first edition of the ICL [8] was organized in 2021 with limited student involvement.) The competition was supported by the Smart O.C.A. (Smart Online Challenge Activity) online game platform [9] and was managed by the authors assisted by 15 tutors for a total of 112 hours of training and competitions among the classes. The involvement of the ICDD students in the experience of the ICL organization pertained several different aspects including design of the format, selection of the question set, and the online conduction of the activity during the training and different phases of the competition.

Plan of the paper In Section 2 we present the format adopted for the organization of the ICL competition. In Section 3 we describe the experiential learning process adopted for the university students involved in the initiative. Finally, in Section 4 we present a summary of the outcome of the entire activity using data collected during the 2022 edition.

2 An Overview of the Italian Coding League 2022 (ICL 22)

The second edition of the Italian Coding League was proposed to Italian Schools by the University of Genoa. In line with the European Commission's Digital Education Action Plan 2021-2027, with stress on the need for basic education in computer science for all School levels, the Italian Coding League proposed to teachers and students a competition built on top of the Proposal for National directions for Teaching Computer Science issued by the CINI Computer Science and School Laboratory. In this context, special attention has been paid on the following topics: algorithms, programming, data and information. The teaching model designed for the competition was also made explicit to teachers and related to the syllabus of the Pedagogical Certification on the Use of Digital Technologies run by the University of Genoa in the context of the EPICT (European Pedagogical ICT Licence) Certification [10]. Gamification is inherent in the Italian Coding League format. Smart O.C.A. is an online multiplayer game platform that can be played both on students' devices and on the classroom interactive whiteboard. Each player (individual or team) is represented on the virtual board by an icon assigned to his or her virtual "marker." The player rolls the dice and proceeds on the game cell. On each cell the questions appeal once accompanied or not by multimedia elements (videos, pictures, texts). The edition took place during March 8 - 25, 2022 involving 609 students from 29 classes from 9 Italian regions. The activity was managed by the organizers assisted by 10 tutors for a total of 112 hours of training and competitions with the classes. Students logged in from their classrooms took on the challenge, consisting of a series of questions on computational thinking and coding, with the support of a university tutor. As mentioned at the beginning of the section, the questions were designed according to the Proposal for National Directions for Teaching Computer Science in School, and the classes received feedback on the areas of computer science on which they were most prepared during the competition. In a first selection phase, each of the 29 enrolled classes with the help of their tutor participated in a challenge consisting of 15 questions. The resulting ranking was based on the number of correct answers, the time required to complete the challenge, and the interest and enthusiasm shown during the activity. Responses from individual students in a class (or small groups) were aggregated using Wooclap, an online survey web app. The answer most voted by the class was then entered by the tutor to continue in the game. To complete the activity, the same challenge was then repeated in the following days by teachers to their students who tried to tackle the questions individually. The final match, held on March 30, 2022, was organized as a real competition among the 13 classes selected on the basis of the scores acquired during the first phase. The average score obtained by all classes in the selections was taken as the threshold for admission. All 13 finalists had to tackle a new challenge based on 17 questions on algorithms, data, and programming. Each question was associated with one of the 17 Agenda 2030 themes. The 13 mentors guided the different classes using separate video conferences. All the classes were able to see the shared game board with the current location and points earned by each other class. The two winners received a ticket to the 2022 edition of the Festival of Science of Genoa.

The Smar O.C.A. platform engages students in a competition based on gamification capable of motivating and focusing students' attention on the learning task. Students participate in the game as a class and then also individually to derive a proficiency measure for the class as well for individuals. Thanks in part to the skill of the teachers, groups of experts were created in the classrooms: those at the blackboard solving problems under the directions of their classmates; those from their tablets looking for information to share; and those in groups solving problems and sharing them in the class. A large "cognitive workshop" was activated in all classes with great internal cohesion and the stimulus of competition with other classes.

3 Behind the Scenes of ICL 22

The ICL initiative was also an experiential learning activity for the 16 students attending the third-year elective course "Computer Science for Creativity, Teaching and Dissemination" of the Bachelor of Computer Science at the University of Genova in academic year 2021-22 (second semester). The learning outcomes of the course include: "design and conduct hands-on lab activities for introducing beginners to computational thinking and coding". In this section, we take the point of view of the course and discuss the activities in which students were involved, focusing on their outcomes, their practical organization and the learning outcomes for the students.

3.1 Game Design

Question design. The first activity in which students were involved consisted in the preparation of the questions to be used in the challenge. After introducing the students to computational thinking concepts, visual coding languages (Scratch), and to the CINI syllabus they were required to prepare quizzes distributed over three main domains of the CINI Algorithms, Programming and Data syllabus and specifically to the goals for the end of grade III in Secondary School. A further requirement was to formulate them according to the main principles of Computational Thinking, i.e., relying on daily life algorithm examples (recipes, regulations, etc.), and to properties of algorithms, so to distinguish algorithms from ambiguous or incomplete or non-terminating procedures. Programming questions can refer to examples of scripts in Scratch. Starting from an analysis of the questions of the first edition of the challenge, an engaging collaborative work involving students and instructors produced the resulting 32 questions for the two games (15 question for the selection and 17 question for the final). Candidate questions were proposed by students by filling in an online form, organized according to the different learning objectives of the syllabus. Proposals were organized in an online collaborative sheet and students were asked to vote for the proposed questions they liked, and to comment on all questions. The most voted questions were discussed in face-to-face meetings, in which students and instructors deeply analyze them according to different criteria (clarity, conciseness, appropriateness for the age target, diversity, etc.) and several reformulations of questions (and corresponding answers) were discussed to get to the final version.

Algorithms	O-M-A-1. detect possible ambiguities in the description of an algorithm in natural language;	Q9 [12]
	O-M-A-2. express algorithms according to the ability of the performer and reflect on their correctness;	Q1 [12]
	O-M-A-3. write algorithms, including using conventional notations, for simple processes from nature or everyday life or studied in other disciplines;	Q5 [12] Q12 [12]
	O-M-A-4. detect and express the conditions under which these processes end;	Q7 [12]
Programming	O-M-P-1. experiment with small changes in a program to understand its behavior, identify any flaws, modify it;	Q8 [12] Q13 [12]
	O-M-P-2. write programs that use nesting loops and selections;	Q2 [13] Q14 [12]
	O-M-P-3. use modular mechanisms, such as functions and procedures, in a simple way;	Q6 [12]
	O-M-P-4. also write programs using variables of simple types;	Q10 [12]
	O-M-P-5. follow the evolution of processing also using variables that represent the state of the program;	Q4 [12]
	O-M-P-6. use variables in the conditions of loops and selections;	Q11 [12]
	O-M-P-7. restructure programs to improve their comprehensibility;	Q15 [12]
Data	O-M-D-1. recognize whether two alternative simple representations of the same information are interchangeable for one's purposes;	
	O-M-D-2. perform simple operations on symbols representing structured information (e.g., binary numbers, "bitmap" images);	Q3 [12]
	O-M-D-3. use variables to represent processing status;	
	O-M-D-4. use structured variables to represent aggregates of homogeneous data (e.g. vectors, lists, ...).	

Table 1. Scope and Objectives of the CINI Syllabus

In the questions for the second game, a further element of difficulty was the requirement to link each question to one of the 17 Go Goals of the Agenda 2030 (which became a further dimension in the collaborative online sheet). The students are asked to review the proposed questions w.r.t. clarity and possible misinterpretations and ambiguities. The overall collaborative work out of which the final questions emerged spanned three weeks and a total of 16 hours of face-to-face meetings. The produced questions (in Italian) are publicly available in the Genial.ly portal [12,13]. To provide some examples extracted from [13], Question 1 "Defeating Poverty" (first Agenda 2030 topic) is about understanding natural language and basic concepts of logic with links to topics students will see in their ninth grade (Boolean algebra). Question 13 requires code comprehensions: In the considered code a variable is used to maintain the maximum value in a loop used to acquire data from an external source. Question 15 requires to calculate the effect, in this case with an exponential trend, of parasite reproduction after a certain number of months. Finally, Question 17 deals with an example related to network analysis and, in particular, the concept of centrality of a node in a given graph. The considered questions have been associated to the objectives identified by the CINI syllabus: in the selection phase, the domains Algorithms, Programming, Data and Information were considered; in the final phase, a question related to the domain Digital Awareness was added. As an example, Table 1 shows the classification of the questions used in the selection phase of the competition according to the CINI syllabus for the considered topics.

Game board and graphical design. As a second step, students worked on the presentation of the challenge, creating a game board and a graphical layout for the different questions via the Genially editor. The graphical layout for the 17 questions used in the final was inspired to the 17 Go Goals of the Agenda 2030. In the last step the questions were linked to the Smart O.C.A. game instance to provide a multiplayer game experience.

3.2 Game Conduction

After several internal tests, our students brought their game instance to the field by conducting 609 participants during both the selection phase and the final match. The tutors guided the different classes with independent online conferences sessions (via Google Meet). In the selection phase, each of the 29 enrolled classes went through a 15-question challenge with the help of their tutors. During the game, responses from individual students (or pairs) in a class were aggregated using Wooclap, an online poll app. The answer most voted by the class was then entered into the platform by the tutor. Participants were left free to reason and discuss to avoid putting the brakes on the communication mechanisms already rooted in the class. The same challenge was then repeated in the following days by each tutor with the class, with no scores involved, and students first tried to tackle the questions individually, then the voted answers were commented in a plenary discussion to let the correct answer emerge. The final match was organized as a real competition among the 13 classes selected using the scores acquired during the selection phase. Each class, connected as a single team to the Smart O.C.A. platform, had to tackle a new 17-step challenge. A shared game board displayed the teams' position.

3.3 Reflection Phase

The experiential learning activity was concluded by a meta-cognitive [10] activity in which the students were guided in reflecting on the experience. Specifically, after the conclusion of the experience, and through an anonymous Wooclap pool they were asked to answer some open questions, including:

- What were the teachers' objectives in involving you in the ICL experience?
- What was the hardest thing in that experience?
- What was the most useful thing in that experience?
- What do I think I have learned?

In addition, they were asked to evaluate on a Likert scale (1-4)

- How challenging were the tasks you were involved in?
- How do you feel supported by teachers, classmates, learning resources in completing them?

area	topic	#questions	#answers	#correct	%
Algorithms		5	145	75	51,72%
	O-M-A-1	1	29	5	17,24%
	O-M-A-2	1	29	20	68,97%
	O-M-A-3	2	58	26	44,83%
	O-M-A-4	1	29	24	82,76%
Programming		9	261	175	67,05%
	O-M-P-1	2	58	43	74,14%
	O-M-P-2	2	58	43	74,14%
	O-M-P-3	1	29	19	65,52%
	O-M-P-4	1	29	5	17,24%
	O-M-P-5	1	29	24	82,76%
	O-M-P-6	1	29	21	72,41%
	O-M-P-7	1	29	20	68,97%
Data	O-M-D-2	1	29	16	55,17%

Table 2. Responses to selection phase questions referenced to the CINI syllabus

The experience was perceived as challenging (all answers were 3 and 4) but the students perceived to have been supported enough (87,5% of answers were 3 and 4). The answers to the open questions were discussed in the final meeting, clustering individual answers to open questions and identifying them as disciplinary, pedagogical, or soft skills. According to the obtained answers, the main skills recognized by the students to have been achieved or strengthened by experience are:

- Disciplinary skills:
  - creating content aimed at middle school;
  - matching CS knowledge and the topics required by the syllabus;
- Pedagogical skills:
  - focusing on the specific skill/knowledge assessed by a question;
  - formulating questions adequate to the target;
- Soft skills:
  - teamwork and project management;
  - inventiveness and creativity.

In the same metacognitive final feedback, the main difficulties related to the experience emerged as formulating clear and unambiguous questions and linking the questions to the Agenda 2030 objectives. Indeed, though the added value of an interdisciplinary approach was well recognized, the need to involve domain experts as advisors and/or reviewers emerged. Though the online management of the challenge was not simple, this was not perceived as a difficulty by the students.

Being part of a bachelor's degree course, the proposed activity was a great opportunity for students to discuss their experiences, to propose and test their work to a real audience, therefore empowering their soft skills, and for instructors to establish a sense of trust and openness with students according to the experience-based learning criteria proposed in [11] and, specifically, concrete experience, active experimentation and reflective observation.

4 Assessment using Data Collected during the Competition

As the questions of the challenge were based on CINI framework and specifically on items algorithms, programming, data we could have a main picture of the skills and competences performed by all the participants and also at class level. The analysis of the 435 responses to the 15 selection questions sent by the 29 classes the statistics obtained are shown in Table 2.

The questions related to algorithms, e.g., everyday algorithms, properties of algorithms, distinguishing algorithms from ambiguous or incomplete or non-terminating procedures, etc., were found to be the most difficult to tackle. Many of the programming questions were related to examples of scripts in Scratch, a language already used by all the classes, and thus were most familiar. As for the final, the 17 questions (thus with 221 total responses accepted) mainly covered the areas on algorithms and programming with more even coverage than in the selections and one question on digital skills as described in Table 3. In the final as well, questions on algorithms represented the greatest difficulty. As expected, given the selection of classes that was based on the average score obtained in the selection match, the success rate improved significantly in all categories and particularly in the Algorithms (from 51% to 71%) and Data (from 55% to 73%) categories.

Finally, we present the analysis performed on the individual challenge, in which students individually attempted to answer the questions, comparing it with the data from the selection phase collected through Wooclap. Notably, the latter data are collected at a finer level of detail than the data from the previous analysis. Specifically, each record identifies a student (or a pair/small group of students per tablet) rather than the entire class. Table 4 shows the response success rate for each skill area in the selection phase (with class- and student-level data) and the individual phase (with student-level data).

area	topic	#questions	#answers	#correct	%
Algorithms		7	104	74	71%
	O-M-A-1	3	39	34	87%
	O-M-A-2	1	13	13	100%
	O-M-A-3	3	39	22	56%
	O-M-A-4	1	13	5	38%
Programming			78	61	78%
	O-M-P-1	1	13	6	46%
	O-M-P-2	1	13	13	100%
	O-M-P-3	1	13	12	92%
	O-M-P-5	2	26	18	69%
	O-M-P-6	1	13	12	92%
Data		2	26	19	73%
	O-M-D-1	1	13	13	100%
	O-M-D-3	1	13	6	46%
Dig. Comp.	O-M-N-2	1	13	11	85%

Table 3. Responses to final phase questions referenced to the CINI syllabus

In the individual challenge, the percentage of correct answers improved significantly for both the data and algorithm domains. In contrast, there seems to be no learning effect on programming. This could be attributed to the lack of data from some classes on the selection phase. In fact, not all classes decided to participate in the individual challenge. Finally, a comparison between the class-level and Wooclap-level selection phase shows greater variability in responses for the data topic, which increases again in the individual phase. In order to make the ICL a learning opportunity for all participating classes, we gave a feedback to each class about their own results. The feedback provided the class with an analysis of the level of proficiency achieved in each computer area. Specifically, the document offered a visual analysis of the data with radar charts at both the scope and individual question levels. Finally, it contained solutions and explanations of the exercises.

	Data	Algorithm	Programming
Selection phase (Class-level data)	52%	52%	67%
Selection phase (Student-level data)	29%	47%	67%
Individual challenge	79 %	63%	66%

Table 4. Correct response rate by topic area for the selection and individual stages.

5 Conclusions

ICL enabled multiple levels of learning for all the actors involved: university students, school classes, we who are writing and that designed the experience. It was a stimulus for university students to design an innovative training course based on the methodology of gamification and the use of digital technologies; it was an opportunity for growth for the school students who participated. It was a stimulus for the proponents who wanted to use a framework specifically built for School contest (the CINI Proposal for National Directions for Teaching Computer Science in School), to offer a learning path with explicit skills objectives and at the end have the possibility to have a clear measure the obtained results. The future goal is to make the whole process more and more sound and “fluid” by providing the possibility for more schools to participate in the next editions of the ICL.

Acknowledgements. The authors would like to thank the students of the third-year bachelor course ICDD and the tutors of the 2021 and 2022 editions of ICL for their support and engagement in participating in the initiatives.

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