An inclusive summer camp based on coding and educational robotics to discover the planet Mars through digital storytelling with Scratch

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Introduction

This work presents a summer camp organized under the national educational programme (PON) "Social inclusion and fight against marginalization" held in 2018 and based on digital storytelling with Scratch, addressed to 18 male students and 12 female students of a lower secondary school. Its main goals were to rebalance situations of socio-economic disadvantage in an area on the outskirts of an important metropolitan city and to help break down gender stereotypes persisting in our society, which pose an obstacle preventing girls from accessing STEM (Science, Technology, Engineering and Mathematics) disciplines, while strengthening key competences defined in the reference framework indicated by the European Parliament (2006/962/EC). In the awareness that it is possible to stem the growing epidemic of learning disabilities and school dropout by providing a wide variety of experiences available to students, it was decided to engage them with interesting activities to keep up with the changing world, using technology.

The methodology adopted in the summer camp is the TMI (Think-Make-Improve) and the learning tools used were coding and educational robotics, which are suitable for preparing practical and motivating activities that can fuel interest and curiosity (Eguchi, 2010; Alimisis, 2013) and to ensure the involvement of those who experience a special educational need. As demonstrated by research conducted in this area (Resnick et al., 1996; Alimisis, 2009), robotics has entered not only rehabilitation contexts but also educational and school environments of all orders and grades, focusing each time on different perspectives: inclusive, interdisciplinary, specific to single subjects (Pennazio, 2018). In an educational context, robotics represents a new field of research which, inspired by the elaborations of the constructivist paradigm (Piaget & Inhelder, 1970), subsequently revisited by the constructionist approach of Papert (1980; 1992), considers robotic technologies as "objects-with-which-to-think" (Harel & Papert, 1991). The strong link with the narrative approach is the strength of educational robotic systems of this type. In such a structured "technological environment" sociality, shared work and the co-construction of knowledge are promoted (Ackermann, 2002; Pennazio, 2017).

The common thread of the summer camp, led by an astrophysics researcher, was space exploration. The activity consisted in organizing contents of different formats within a coherent system, supported by an open narrative structure, in order to create a story to be developed with Scratch. The participants, organized in groups, practiced the four macro-areas of coding, musical language, textual language, and graphic language. The last two days of camp were entirely dedicated to the assembly and programming of the educational robot Mbot, both affordable and easily accessible, through which it is possible to experiment with fundamental concepts related to the robotic exploration of planet Mars.

Skills developed in the project

In accordance with the recommendations indicated by the European Parliament (2006/962/CE) regarding the skills necessary to adapt flexibly to a world characterized by strong interconnection, the summer camp has tried to enhance some of the key skills defined in the reference framework. In particular:

1. *Communication in the mother tongue* – Communication in one's mother tongue is the ability to express and interpret concepts, thoughts, feelings, facts, and opinions in both oral and written form, as well as to interact creatively on a linguistic level in various contexts. During the two weeks, the students practiced both their oral and written communication skills, discussing the design choices, seeking, collecting and processing information, critically analyzing the reference texts, formulating arguments in a convincing and context-appropriate way, composing the screenplay of an opera and presenting the project to fellow students and teachers. As the context was that

of a summer camp, it was particularly easy to maintain a positive and serene attitude, with the exception of a couple of episodes, a critical and constructive dialogue.

2. *Communication in foreign languages* – Since most state-of-the-art information relating to the scientific topic in question is in English, the students practiced their oral and written comprehension skills through the analysis of information sources (primarily the scientific websites of the two government agencies ESA and NASA, or the English Wikipedia). While the majority decided to carry out the project in Italian, starting from translated content in English, some preferred to develop the project in English, with both audio and text contributions.

3. *Mathematical skills in science and technology* – Mathematical skills is the ability to develop and apply mathematical thinking to solve problems not only in the school environment but in any daily situation that requires it. As part of the digital storytelling with Scratch, moving and sizing objects on stage in order to create perspective effects involves the application of indexed mathematical formulas within programming cycles. In this case, mathematics combined with coding allows one to add three-dimensionality to the scene. The skills acquired in the scientific field – in particular relating to planet Mars and its exploration, introduced by the astrophysicist and independently examined in depth by the participants through research – allowed them to understand, represent and talk about phenomena that occur on the red planet (sandstorms, color of sunrises and sunsets, different movements with respect to the Earth due to the different gravity) as well as the appearance of some characteristic morphologies (canyons, craters, volcanoes, plateaus). Mathematical and scientific knowledge have been put into practice thanks to the skills in the technological field, through coding with Scratch, the use of specific tools to create new sprites and give voice (through audio content acquisition and manipulation software) to the programs, and through examples of educational robotics. By presenting realistic missions on the Martian surface – past, present and future – it was possible to contribute to student developing critical thinking to recognize the basic aspects of scientific investigation and to be able to communicate conclusions and reasoning.

4. *Digital skills* – Digital skills consist in knowing how to use information society technology with familiarity and a critical spirit. Participants used

computers to find, evaluate, produce, present, and exchange information. They did this using text editing applications, spreadsheets, image and sound editing applications, audio and video format converters, approaching new computer applications and exploring their functions and potential. They also used other electronic devices (microphones, video cameras, cell phones) to acquire audio and video material useful for the development of the story and the documentation of the project. With regard to the storage, management and use of information, the issue of source reliability was discussed in depth and the restrictions related to copyright in the use of content were presented, as well as the risks associated with the Internet. An attempt was made to promote awareness of how ITEs (information technology and equipment) can assist creativity and innovation, warning participants about the issues related to the validity and reliability of the available information and the legal and ethical principles that arise in its use.

5. *Learning to learn* – Learning to learn is the ability to persevere in learning, managing time and information effectively, both individually and in groups. The students had two weeks to think, develop and implement their project. Participants worked collaboratively, learning to seize the benefits that can come from a heterogeneous group. An attempt was made to help them organize their learning, independently assess their work and seek advice, information and support, both by addressing their peers from other groups and via the reference figures present in the classroom. Special emphasis was placed on always keeping a positive attitude, which includes motivation and confidence to persevere. Addressing problems in order to solve them is useful both to the learning process itself and to manage obstacles and change.

6. *Social skills* – Collaborating with peers in the implementation of the activities and projects, respecting the common rules and assimilating the sense and need for respect for civil coexistence, committing to completing the project work undertaken: these are the social skills that we tried to carry out in the various groups. The common basis of these skills includes the ability to communicate constructively in different environments, to manifest tolerance, to express and to understand different points of view. One should be able to handle stress and frustration and express them constructively, distinguishing between the personal and professional spheres. This has not always been the case, especially in some groups.

Think-Make-Improve methodology

According to the constructionist philosophy, people learn best when they are engaged in personally designing and building their artifacts by sharing them within a community because, by building an external object to reflect upon, they also feed their internal knowledge (Bers et al., 2002). The experience presented here is based on the Think-Make-Improve (TMI) methodology taken up by Martinez and Stager (2013), which allows one to reach the desired artifact starting from an idea and the search for the solution to all the problems that arise in the making. This method helps planning with a problem-solving approach and avoids proceeding towards the solution in a random fashion, but rather by reasoning before facing the problem and analyzing what has been done once the solution has been achieved. It starts with the contextualization of the challenge, the organization of the work and the start of the activity.

The students, organized in groups of up to six and as heterogeneous as possible, confront each other and eventually reach a shared solution. In this phase, they were granted plenty of time necessary to understand how to face the challenge, with support when needed to evaluate some aspects related to the feasibility and implementation difficulty of the proposed ideas. Next came the content preparation (images, texts, audio and video) and the program development, which takes place through mediation between the members of each group. Initially, the design is done on paper, through flowcharts and algorithms, and then moves on to the implementation of the code. Step by step, checking the functionality of the program leads to its improvement. Mistakes become ideas for redesign. At this stage, a reflective attitude allows one to recognize the error as an opportunity for improvement. By doing so, learning is authentic and there is a strengthening of motivation, persistence in the face of the challenge. The desire for experimentation grows because it becomes clear that, by experimenting and making mistakes, we learn and improve. Some more easily, some less, students learn to manage the frustration induced by seeing that what has been achieved does not always conform to the original idea. In this case, we start with the idea to rework the path.

The iterative design methodology can also be found in the words of John Dewey, initiator of pedagogical activism: «Once more, it is part of the educator's responsibility to see equally to two things: First, that the problem grows out of the conditions of the experience being had in the present and that it is within the range of the capacity of students; and, secondly, that it is such that it arouses in the learner an active quest for information and for production of new ideas. The new facts and new ideas thus obtained become the ground for further experiences in which new problems me presented. The process is a continuous spiral» (Dewey, 2014). This continuous spiral process is very similar to what is experienced daily in the world of scientific research.

If Dewey already talks about the laboratory activity as an activity where different phases follow one another – planning, action, experimentation, testing, feedback, adjustment, and then returning to action again – we find remarkable similarities with the thought process that Resnick (2007; 2018) used in his experiments at Lifelong Kindergarten: it is always a guided practical and cyclical process, where, in Resnick's case, the dimension of play and personal attitude is introduced (Di Stasio & Nulli, 2021). A playful dimension that has also been pursued in the summer camp.

Coding and Educational Robotics

Whereas the common thread of the summer camp is space exploration, the tool through which the participants were able to make their "journey" and develop their creativity is coding, a transversal discipline based on computational thinking. When you want to give life to an idea through coding, the concepts underlying that idea must be very clear to those who practice it, in order to be able to exhaustively define the steps (algorithms) to be performed by the programmable device. The programming exercise allows one to dig deeper – raising doubts, proposing solutions and investigating the possible paths that can be taken to reach the solution – and inevitably leads to a better understanding of the concepts themselves. In this context, Scratch is a very powerful tool. It is a visual programming environment, developed by the Lifelong Kindergarten research group at the Multimedia Lab of MIT in Boston, particularly suitable for teaching the basics of programming to students, even very young ones, to develop computational thinking and problem solving skills.

Organization of the summer camp

The summer camp took place during ten meetings lasting three hours each, for two weeks (30 hours in total). 18 male students and 12 female students from a lower secondary school participated. The participants were divided into groups, as heterogeneous as possible, of maximum six each. Each group defined the story to be developed, identifying the main characters and the setting on the red planet. The groups worked independently. During the entire duration of the summer camp, the four macro-areas of coding (development of the story), musical language (creation of the soundtrack with musical instruments), textual language (creation of dialogues and narration) and graphic language (creation and adaptation of sprites and backgrounds) were developed in each group. The researcher and tutor acted as facilitators of the learning process.

In order to provide a scientific background for the development of the adventures on the red planet, in the first meeting students were provided with basic astronomy concepts related to the solar system and Mars, including recent photographs and videos from NASA and ESA, and to the exploration of the planet (probes, landers and rovers of NASA and ESA, with particular reference to those that in the summer of 2018 were operational on the planet, Curiosity and Opportunity). A few possible missions to be developed were also presented: looking for past forms of life, building an environment in which one could live, growing vegetables, exploring cavities, looking for water underground, and leaving towards Earth. In the first meeting, the issue of source reliability and image copyright was dealt with in depth, which is fundamental when creating content intended for publication.

Digital Storytelling with Scratch

All participants had already used Scratch at school, already since primary school. Nevertheless, the basics of programming with Scratch were revised: interface and terminology of the working environment, execution of a single command and sequence of executions, loops, conditional constructs, variables and lists, operators, messages and timing of events, cloning, use of sounds and costumes. In addition, graphic elements useful for the creation of sprites and backgrounds were explored (such as the difference between bitmap and vector images, image resolution) and examples of digital storytelling with open structure Scratch were presented. Digital storytelling is a narrative created with digital tools that consists of organizing content of various formats (video, audio, images, texts, maps) in a coherent system, supported by a narrative structure, in order to obtain a story. Having defined the initial idea through a short description or a map, the students searched on the internet for the material necessary to investigate the topic of interest in depth. They wrote the story by defining the style of the narrative and translated the story into a script. Once this was done, they took care of collecting images and recording audio and video material. To do this, they were able to occupy various classrooms in the school, transforming them into recording studios. Next, they edited the material together using Scratch.

A description of some of the students' artifacts is reported, highlighting their peculiarities and strengths.

An encounter with the Curiosity rover

The group that developed this project was made up of four girls and two boys, who decided to tell the fantastic story of their encounter with the Curiosity rover, which has been exploring the Martian surface since 2012. Three scenes were represented. In the first one, the blue dawn rises on the red planet, gradually illuminating the rocky outcrops on the horizon. The Sun, much farther from Mars than it is from Earth, appears smaller in the sky than we see it from our planet. In the second scene the main characters of the story appear, obviously dressed in the classic spacesuit that allows extra-vehicular walks: four female astronauts, a male astronaut and the small rover, who tells them about its recent discovery of organic molecules on the planet. In the third scene, the explorers come across the remains of Schiaparelli, the ESA lander that failed its landing maneuver on 19 October 2016 and crashed on the Martian surface. Curiosity tells them the reasons that led to the mission's failure. All the images used (for backgrounds and sprites) are realistic and taken from the NASA and ESA websites. The dialogues were reported in the comics, as text, and reproduced as audio, obtained using a mobile phone sound recording application or directly with Scratch, in case the computer used was equipped with a microphone. The role of "Curiosity" was played by a dyslexic boy, who managed very well, and with great satisfaction, to give his voice to the robot. The soundtrack that accompanies the story, in the scenes without narration, is original, created during the hours of the summer camp on the piano by a boy who had a problem related to language, due to a hearing system damage. Only recently he had been able to hear normally, thanks to an external device, and his desire to devote himself almost entirely to the soundtrack (helped by another younger boy, from another group), as well as inserting it into the Scratch program, was seconded.

Storytelling through the map

The group that developed this project consisted of four young people who decided to accompany the user in the discovery of the red planet using an interactive map. The protagonist of the adventure is mBot, with a sprite specially created and equipped with multiple costumes. There are about twenty scenes available but they do not follow one another, as in the case of the previous project, but it is the user who chooses where to go. The story begins with a rocket that starts from Earth and arrives on Mars, reproducing the correct changing perspective. Once on Mars, mBot is released from the satellite and lands on the Martian surface. Subsequently, a map of Mars appears with ten points of interest visited by Curiosity: clicking on these, the main characters is projected onto the chosen location, with a change of background and the main character in the foreground, starting to describe the place through recorded audio. Images and descriptions are realistic, taken from the NASA website dedicated to Curiosity, suitably translated from English into Italian, and summarized by the students. The members of the group divided the places of interest and, once the texts were prepared and the audio contributions were recorded, they developed the code together. In one of the destinations of the project, they also set up a “pong” type game, to insert the playful dimension in their product.

A spy in space

The artifact was produced by two girls. It is a very articulated fantastic story, represented with extreme attention to detail. A researcher is presenting at a conference a mission devoted to the search for water on Mars. Already in this scene it is evident how the two authors paid attention to details, for example by changing the image on the “laptop sprite” at the same time as that projected on the "big screen sprite". After the explanation, the scene changes and moves to a shot of the rocket with the hatch open waiting for the astronauts to arrive. Before their entry, a small dog slips into the rocket and inside finds a robot that turns out to be a spy with the aim of finding out what humans are up to on the red planet. Once the astronauts have also arrived, the rocket closes its hatch and starts, after the countdown. In the next scene, footage of the Solar System planets appears and the voiceover explains why the robot wants to hijack the rocket towards Jupiter, away from humans from Mars. The story continues, until the dog and the robot end up becoming friends, although they will have to say goodbye because the dog prefers to return to Earth, while the robot wants to be dropped off on Mars. The soundtrack was composed by the two students using the electric piano and the mandolin. The creativity of the authors is impressive, as are the technical solutions that allowed them to implement the idea.

Digital storytelling with an open narrative structure

Also in this case, the story that is told is fantastic but, unlike the other examples of digital storytelling reported, its structure is open: the user can choose what to do and, based on his or her choice, the story takes different routes. The group that carried out this project preferred to use English, also for the audio content. From a technical point of view, the students were able to reproduce a sandstorm, a very common phenomenon on the planet Mars, using cloning.

Educational Robotics with mBot

Once the digital storytelling part was over, the last two days (therefore six hours) were entirely dedicated to educational robotics with the assembly of the mBot robot and its programming via mBlock (a programming environment based on Scratch). Each pair of students was given an mBot kit to assemble, following the instructions in the package. The groups assembled the robot in complete autonomy, in some cases asking for the collaboration of fellow students. It is worth noticing the great dexterity and skills of some students with specific learning disorders who, in addition to quickly assembling their robot, helped several other groups in the construction.

While still in the context of the exploration of planet Mars, the similarities between the little robot and Mars robots were discussed and various programming challenges were proposed with mBlock:

- to drive the mBot by turning on the two lights;
- to make the mBot stop at an obstacle, using the ultrasonic sensor;
- to make the mBot follow a path, thanks to the infrared sensor;
- to program the mBot to move autonomously.

To face these challenges, the students familiarized themselves with the sensors available in the mBot basic kit. The ultrasonic sensor – positioned in the robot's eyes (one eye is the ultrasound transmitter, the other is the receiver) – allows mBot to know the distance to the object in front of it, without touching it. The transmitter emits an ultrasonic signal that is reflected by the object and returns to the receiver. By measuring the interval between the instant the signal started and the instant the reflected one was received – knowing that sound propagates at a speed of about 344 meters per second (in air at room temperature) – the distance between the robot and the object can be calculated.

To follow a given path, such as a black line on a white background, mBot uses two infrared sensors located frontally and facing downwards. When the infrared radiation emitted by the transmitter reaches a white background, it is reflected and the sensor is able to detect it. When it hits the black line instead, it is absorbed and the sensor detects nothing. There are two sensors and four possible combinations, corresponding to four values returned by the line tracking sensor: once these are read, they allow the robot (the programmer) to decide which way to move in order to stay on the line.

The final challenge presented the students with the problem of remote control of a robot on Mars, linked to the fact that by sending a command from Earth, the robot will receive it only after several minutes. This is because Mars is 12.7 light minutes from the Sun (meaning that sunlight takes 12.7 minutes to reach Mars) while Earth is 8.3 light minutes from the Sun. Both planets revolve around the Sun at different speeds. So, depending on where the two planets are located relative to one another, mBot may have to wait a long time before receiving commands. Participants simulated the delay in receiving commands from mBot: the code is very similar to that used to drive mBot in the first challenge, the only difference being the need to wait for a "delay" before executing the command.

The students then experienced what it means for mBot to receive a command several seconds after the command was given. It became clear that it is not practicable to pilot the robot from Earth, because the control would not be timely: the robot would risk colliding with the obstacles it encounters along its path. The students thus understood that, in this case, it is essential to instruct the robot so that it can figure out for itself what to do when it encounters an obstacle. In other words, they need to program it, i.e. to create a code (very similar to the one created in the first challenges) and transfer it to its internal memory, so that it can execute the commands independent of us, even on Mars.

Evaluation

The project presented here was an opportunity for the participants to be active protagonists within the school community. The activities of the project, with a laboratory and operational style, worked on the motivation and involvement of the students, through strategies such as cooperative learning, moments of peer tutoring, enhancement of multiple intelligences and creativity, also thanks to the use of multimedia and digital tools. Students built new skills through an inductive process that tested new and previous skills. They understood that nothing important works the first time: the only way to do the right thing is to carefully observe what happened when it didn't work (Stager, 2006). An evaluation was conducted throughout the experience, in the least intrusive way possible, listening to the discussions within the various groups from aside and observing, without interfering, the artifacts take shape. At the end of the summer camp, the various groups presented their artifacts and were asked to evaluate the project and the experience (methodology, organization, content, learning) by highlighting strengths and weaknesses, always trying to keep criticism constructive. One of the major difficulties encountered was related to the relational aspects, rather than the technical and implementation aspects of the proposed challenges.

Conclusions

The learning outcome in a lab activity such as the one presented is determined by the planning and management methods of teachers and educators, who must know how to combine different aspects: an appropriate theoretical background, the skills of the people involved, the curriculum, and the organization of the learning environment. The synergy between the world of scientific research – in particular research linked to the development of technologies to observe the universe – and the school world has allowed us to complete this inclusive experience that managed to excite students and contributed significantly to developing computational thinking, team working, problem solving aptitude and digital skills, in a particularly interesting context involving the STEM disciplines: space exploration.

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