Officina Degli Errori: An Extended Experiment to Bring Constructionist Approaches to Public Schools in Bologna

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Abstract In this contribution we describe an extended experiment to bring constructionist approaches to public schools in Bologna. Specifically, we focus on our latest project called *Officina degli Errori*, which is an extended teacher training program for primary school teachers based on tinkering. We highlight our motivation, the structure of *Officina degli Errori* and the lessons learned co-designing the activities and implementing them in the reality of public schools in Bologna. We also interviewed teachers to understand the critical issues affecting implementation of constructionist approaches in public primary schools.

Keywords Constructionism · Tinkering · Public primary school · Teacher training

1 Introduction

The basic goal of *Officina degli Errori* is to provide teacher training and strong support to constructionist practices in the classroom through tinkering. Through this project, we are also interested in exploring and understanding what changes are needed in the school's organization to enable proper implementation of these practices. In Sect. 2, we describe the origins of the idea, its associated values, and the close collaboration between the researchers (science) and teachers (education) involved in co-designing the activities for schools. Section 3 describes the activity carried out from September 2018 to June 2019, lasting the entire school year. Conclusions and future prospects are discussed in Sect. 4.

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2 Values, Aims and First Round of Co-design

The authors launched *Officina degli Errori* after more than five years' involvement in science education and outreach activities. We begin our description of our approach by briefly mentioning how we came to be involved in constructionist practices. The starting point was a typical lecture given at "Marella" primary school within Istituto Comprensivo 12 (IC12) in Bologna, which had been requested by S. Rini, a teacher at the school at the time. The lecture was on cosmology and was delivered by S. Ricciardi. As a researcher at INAF (National Institute of Astrophysics) in Bologna, S. Ricciardi was actively involved in analyzing data and publishing papers on the European Space Agency (ESA) Planck satellite [1]. She prepared a lesson for seven-year-olds on the CMB (Cosmic Microwave Background), the first light in our universe, and about the Planck satellite and her personal involvement in the research. The lesson went very well, the children were amazed, and everybody was satisfied. It is important to say that this was the expected outcome, given the known appeal of the subjects, which include dark matter and dark energy, and the origin and fate of the universe. As F. Villa, the third author of this paper and fellow INAF researcher, had had similar experiences, we discussed whether the students truly learned something from such lectures. We were particularly interested in the "wow factor" of experimental cosmology and, more generally, astronomy, and whether the experience was truly positive for everyone in the science education classroom.

We discussed it with teachers and concluded that children who were already interested in STEM subjects (science, technology, engineering and mathematics) were certainly inspired. We noticed that this was not the case for all children. We believe self-stereotypes (socio-economic conditions, gender issues, family culture) are already strong in elementary schoolchildren [2], and, hence, that some children might not feel they are smart enough to be involved in STEM.

This reflection made us rethink our work in the classroom and inspired us to find a better way to express our values, including the basic concepts of trial and error in science research, and the sharing of knowledge and skills.

We identified what, in our view, are the top characteristics that should be met by all educational activities in the sphere of astrophysics and STEM in general:

- (i) **Democratic:** activities should be designed to be truly inclusive.
- (ii) **True/real/honest:** we have to tell students the truth about our research work, including the failed attempts and errors, especially when we do frontier research. We also have to let them know that scientists cannot know everything; they might be unable to explain natural phenomena; research is about constructing knowledge.
- (iii) **Meaningful:** activities should be relevant to students, so they can relate to them.
- (iv) **Empowering:** the learning process must be designed so that students feel they belong to the STEM environment, and feel empowered by the process itself.

Frontier research is based on new ideas, and exploring new techniques and technologies. Obviously, there is no set road map to follow to get to the final destination,

since most things are under development, and researchers use their expertise to build and develop things from scratch. In more than 15 years' experience developing the ESA Planck satellite and more than 20 years developing new instrumentation and codes for astrophysics, we have come to see that creativity is one of the main drivers, especially at the start of a research project.

Although there is no doubt that (frontier) research requires creativity, children generally have a different perception of research (and researchers). Hence, another characteristic should be added to the list:

(xxii) **Creative:** activities should be designed to stimulate creativity and invention.

We had an opportunity to study and improve our understanding, thanks to the online material and MOOC (massive online open courses) offered by the Tinkering Studio at the San Francisco Exploratorium [3–5]. We also drew inspiration from the work of Mitch Resnick and the Lifelong Kindergarten group, and their vision of a STEM pedagogy that aims to be inclusive (low floor), democratic and, at the same time, allows projects to evolve (high ceiling), allowing children to build knowledge that is personal and meaningful to them (wide walls) [6, 7].

Tinkering is a holistic way to engage people in STEM subjects, by mixing them with art and combining hi-tech materials with low-tech, recycled ones. Knowledge is not merely transmitted from teacher to learner, but is actively constructed in the mind (and the hands) of the learner. Constructionism [8] suggests that learners are more likely to develop new insights and understandings while they are actively engaged in making an external artifact. This method supports the construction of knowledge within the context of building personally meaningful artifacts, and the more self-directed the work is, the more meaningful the learning becomes.

From 2014, we offered several workshops to students in our local community based on the activities originally developed by the Tinkering Studio. We have been collaborating with teachers to design, promote and deliver hands-on, self-directed and playful activities to engage children in STEM, focusing particularly on gender inclusion [2].

By 2017 our labs had matured and were ready to be taken to a larger arena. Hence, in October to December 2017, we took an informal program of four tinkering activities to Bologna's Museum of Industrial Heritage and named it *Officina degli Errori*. We worked with a group of 20 children aged 6–12, over four workshops held on Saturday afternoons in the museum's conference area [9–12]. In the 2018/2019 school year, we offered a training course at the museum for primary school teachers in Emilia Romagna, to help them to become more autonomous tinkerers in their classrooms, and also to develop new insights into how these practices can work in the ecosystem of Italian public schools. These activities were attended by around 16 teachers and around 400 students. We also hosted a shorter version of this training course at Istituto Comprensivo 12 in Bologna, involving 20 teachers and their students (about 500).

3 *Officina Degli Errori: Tinkering Goes to School*

Officina degli Errori was an extended teacher training program lasting from September 2018 to June 2019. We organized this experience in three blocks:

Experiencing: We organized three intensive sessions in early September, where we developed the building blocks. We presented the constructionist framework in pedagogical terms, drawing parallels with the way the scientific research community works, and we discussed the ideas of constructivist epistemology, following the path of Piaget [13] and Khun [14].

We hosted three hands-on workshops where teachers experienced the constructionist approach through tinkering. We had a group of 15 teachers and three facilitators and we proposed several classic workshops originally developed by the Tinkering Studio, which we tailored to our audience (e.g., scribbling machines, paper automata, marble machines);

Engaging: we provided the teachers with a kit containing 9 motors, 20 cables, and 20 battery holders so they could try the scribbling machine with their classes, and hopefully continue using the materials in other creative ways. We invited the teachers to come to the museum with their students and fellow teachers to participate in a workshop, conducted by experienced facilitators. We also invited another teacher, who had already participated in the class workshop, to be a facilitator. This gave us a good student/facilitator ratio of about 6 to 1, and we created a relaxed environment where teachers could facilitate a challenging workshop, perhaps for the first time, without feeling overwhelmed. We also provided a space where teachers could just observe their students and reflect, without the urge to intervene;

Reflecting: we gave teachers more than four months to try different things in their classrooms, providing them with feedback and assistance. We also asked them authentic questions to help them and ourselves reflect. We asked them to describe their feelings when they first tried tinkering as “students.” Specifically, we discussed group composition, how they prepared the groups and how things went, focusing particularly on the participation of girls. At the end, we asked them to think about whether tinkering could be organized in their schools, in terms of space, time, and human resources. We also asked them to report their activities to the other teachers in a final session in late June. The final step from our point of view was a recent interview with some of the teachers.

Our goal was mainly to bring tinkering and constructionist approaches to public schools in Bologna, especially in areas where there is a higher risk of student dropout or difficulties integrating hands-on STEM workshops in formal school activities. This means supporting teachers far beyond the workshops, and helping them with all they need to get started. For this reason, our program was offered free of charge and hosted at the Museum of Industrial Heritage in Bologna. We gave teachers a kit they could use in their classrooms, and the opportunity to facilitate a couple of tinkering sessions in relaxed conditions. We also gave them some guidance on collecting materials and designing new settings. The main differences with earlier

training courses we had organized were the time scale (very extended), the ability to offer materials free of charge, and the commitment to each teacher we trained to facilitate at least one workshop with their students.

4 Conclusions and Future Prospects

From a preliminary analysis of the reports and interviews with teachers, it is clear that this experience was very successful in terms of the teachers' engagement, the quality of the materials and the support provided. Constructionist practices are difficult to implement in schools, and are contingent on teachers making a special effort. One common issue for schools is the availability of physical space. In the schools that have an *atelier creativo* (or a similar environment) or access to one, teachers do tinkering more often (every day/three times a week), and the practice is easier to incorporate into their everyday learning environments. When such settings are not available, sessions are less frequent and more intensive (e.g., one full week of tinkering twice a year). Adapting a classroom for tinkering can be demanding even for a teacher who already uses cooperative learning and innovative teaching styles (e.g., *scuola senza zaino*), simply because there is not enough space to store materials and tools. Teachers have to re-configure spaces every time they use them. Another important issue is the number of facilitators available. We suggested working as a pair with the other class teacher (all the classes have a *tempo pieno* schedule—full-time, including afternoons—and two main teachers, or are module-based with at least three teachers) but this was not always possible. It is extremely hard to facilitate a workshop in these conditions, with only one teacher to about 28 students, especially if there is no dedicated environment. Conversely, workshop facilitation was more relaxed and productive in schools with a better student to teacher ratio or in schools where co-teaching could be arranged. Despite the teachers' motivation and their readiness to overcome difficulties, they were often deterred by the general constraints of how their schools were organized.

On the positive side, some teachers reported that they intend to include constructionist approaches in their teaching practices, not limiting them to STEM, but also applying them to other subjects (such as language). The focus of training for teachers in STEM and educational technology is often on the devices and the literacy associated with the proposed activities. Instead, our extended training offered a more general "pedagogy," which, hopefully, every teacher can tweak to their interests and their class's needs, building genuinely new knowledge not restricted to a specific discipline.

After this experience, we need to continue analyzing the interviews with teachers and highlight what can really help to establish these practices in public schools, without overloading teachers. We intend to continue designing and offering *Officina degli Errori*, working with any partner interested in spreading the constructionist approach and tinkering in Italian public schools. In today's knowledge society [15], the ability to develop 21st-century skills (e.g., [16]) is a crucial question of democracy.

For us teachers and researchers employed by the Ministry of Education, University and Research, it is a firm moral commitment to help schools innovate and offer the best practices in education.

During these years of practice, we developed a particular interest in tinkering as an effective way to engage girls in STEM. To help schools understand the value of these practices, we have launched a preparatory program with the Department of Psychology at the University of Bologna on students' perception of science and technology, with a particular focus on gender differences (190 school students). INAF and IC12 have also co-designed a STEAM (science, technology, engineering, art and mathematics) learning space, which includes tinkering with technology (coding and robotics), storytelling and interacting in pairs, with areas dedicated to experimenting, showing and presenting, and sharing. We were also interested in opening up those approaches to secondary schools, so in the 2018/2019 school year we collaborated with IC12 in the afternoon program "Girls code it better." Eighteen 18 girls aged 11 to 13 took part in the ESA challenge "MOON BASE CAMP," which saw them work with INAF experts, a maker from Bologna FabLab and the teacher who coordinated the overall project on 3D modeling and printing.

We want to offer *Officina degli Errori* to teachers every year, but to be effective we have to engage closely with them and involve them in designing the activities. From our interviews we found that external conditions (mainly the way schools are organized and the availability of space) can be a huge deterrent to these practices. This is why, in addition to tinkering tools and strategies, we also need to provide an "organizational framework" to help them bring those activities to Italian public schools.

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