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Teaching and learning physics in formal and informal contexts

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Summary. — What role does physics play in large-scale science education? This is one of the many questions that we have been pondering over. We believe that research in physics education can make a substantial contribution, especially nowadays, to tackle the problem of the estrangement of the general public from science issues. It is necessary to act on several sides not only by permanently supporting schools and universities to reflect on ways of teaching and learning physics, but also by valuing cultural experiences in informal contexts. The activities of our research group, documented on the website of "Laboratorio per l'Educazione alla Scienza" (LES) (`http:///www.les.unina.it`), are characterized by sharing a non-traditional way of doing science with people. In our experience, the meaning of physical and mathematical theories is understood when people's interpretations of reality resonate with the formal models that physics has of reality. A cognitive resonance model-based approach can help people understand the meaning of models in physics and develop critical thinking. It seems to us that, after years of great deal of efforts, the results achieved have been judged very promising by all subjects involved, and adequately respond to the needs of the territories in which we operate.

1. – Introduction

Why is research in physics education important? In the cultural framework, physics plays a fundamental role in the relationship with history and the other sciences, whether natural or social sciences or humanities [1]. Researching ways of learning and teaching physics is a complex process of reality and requires transversal knowledge in different but interconnected cultural fields [2]. Thus, research in physics education has a direct impact on people and can contribute to the improvement of the whole society. Many studies have shown the importance of physics for the development of critical thinking in people of all ages [3-6]. In this study, we ask what other contribution can physics make to mass science education? [7, 8]. Unlike other natural sciences, physics is interested in things that exist and interact with us, in time and space. It helps us to say that a phenomenon is repeatable if the variables that govern it remain the same. But some variables are more important than others in describing a phenomenon; so we can neglect some of them and describe a system as "isolated" from the environment: in such systems, some

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entities remain unchanged and define the principles of conservation (energy, momentum, etc.) [9]. Ultimately, any understanding of the world requires a careful selection of variables and an appropriate language to describe their relationships: mathematics [10]. Physics therefore requires a certain use of mathematics right from the phenomenological descriptions. When a fact or phenomenon is observed with the aim of acquiring more knowledge about it, it is the whole person, with their experience, their previous knowledge (related to the culture in which they live) and their perceptions, that is involved in the observation. With the first observation of the phenomenon, the person develops a mental image that does not immediately correspond to the image of the real world in physical terms [11]. To understand the phenomenon according to the formal methods of physics, it is necessary to become familiar with its language, consisting of schematization and mathematical tools which are useful for operating on abstract entities corresponding to schematized reality. If all the complexity of the cognitive organization of facts is lost, science domains, and in particular physics, lose their cultural significance and their social value. In 2021, Nobel Prize for Physics Giorgio Parisi raised a serious alarm on the relationship between science and society in Italy. He states that "there are strong anti-scientific tendencies in today's society. The prestige of Science and trust in it are decreasing rapidly. It is possible that this mass distrust in science that reaches our parliament is also due to a certain arrogance of those scientists who present science as absolute wisdom and [...] the slow decline of public school" [12]. This statement is confirmed by national surveys of science learning at all levels of education [13]. As demonstrated by the data collected by the National Institute for the Evaluation of the Education and Training System (INVALSI) in the 2020-2021 school year, there was a significant drop in the scores of mathematics and Italian tests administered to Italian students. Data worsens if students from unfavorable socio-economic backgrounds are taken into consideration. Even if of relative significance, such data is worrying: low levels of competence are one of the most relevant signs of school dropout. The problem is complex and the current difficulties have deeper origins which must be fully understood in order to be able to counter them. We believe that we need to go beyond data and work to develop models of interventions that can respond to people's specific needs. Over the years, our research group has gathered many experiences [14-16]. We operate in our territory through training courses that offer physics educational activities in formal and informal contexts for many different kinds of people: from children to adults, from students to teachers, educators, and families. These experiences are documented on the website of the community "Laboratorio per l'Educazione alla Scienza" which today welcomes a wide educational audience (623 people) made up of students, researchers, teachers, educators. In the following paragraphs, we will try to give a more precise vision of our research in physics education and of the results achieved so far.

2. – Methods: pedagogical references and scientific activities

Over the years, inspired by Vygotskian's social-constructivism [17], our research group has worked to establish a general framework for the revision of disciplinary contents of all levels of education. The Resonance Cognitive Model is the cornerstone of our scientific activities [16, 19]. It is based on the concept of resonance. To get an idea of the model we can think of the case of resonance in the swing. To keep the swing going very efficiently, it is necessary for the oscillating period of the swing and the timed pushes to be in resonance. In the same way, good didactic mediation occurs when people's interpretations of reality are in resonance with the formal models that physics has of reality. In other words, we can say that learning physics is effective when people are helped in the modeling process, and this is possible by taking into account individual cognitive aspects and the socio-cultural background. People who follow our activities are involved both in direct laboratory experiences and in modeling the phenomena under study. During activities we support the cognitive reconstruction of facts by asking our targets to share with us their continuous rethinking of their own way of modeling. In this way, we try to critically engage people with metacognitive strategies aiming to consolidate the things they learn [18]. We involve them in carrying out the activities at home by sharing materials on the LES community website, sharing with them reports and in-depth materials on their experiences. The disciplinary contents we propose are revisited and reoriented for didactic purposes: on one hand, activities are organized around physics' core ideas and crosscutting concepts such as the law of conservation, cause and effect, structure and function [20]; on the other hand, activities intersect other areas of culture such as language, mathematics, technology, and art. We have done our research in many different places. At university, we have developed two teaching activities courses in Physics, both at the Department of Physics "E. Pancini" Federico II and at the Department of Science Education at "Suor Orsola Benincasa" [14]. As far as university teaching is concerned, we have seen that the reorganization of contents with the aim of integrating laboratory experiences (qualitative and quantitative) with theory is a way to help students understand the meaning of models in physics and develop critical thinking. In schools, at all levels of education, we have designed many experimental scientific activities. A recent project, for example, investigated the development of proportional thinking in primary school. With regard to teacher training, we have worked hard for a national training course for primary school teachers which today reaches about one hundred pre- and in-service teachers [15]. As for educational activities in informal contexts, we have started a participatory planning process, which involved the "I.C. Porchiano-Bordiga" school of Naples and the social enterprise "Verde Speranza", on the construction of a pond. The pond was built in a former school complex which today houses numerous third sector associations and will be the place where local school pupils and their families will be able to carry out numerous experimental scientific activities [21]. Activities are based on the analysis of systems and ecosystems with the possibility of measuring physical variables, such as temperature, humidity and dissolved oxygens, with online transducers. Many other scientific-didactic programmes like this one have been developed by our research group [22].

3. – Discussion

Our group's contribution focuses on the role that scientific education can play in the cultural background of citizens [9, 10]. We have learned a lot of direct engagement in the field by bringing more than 300 children at risk from 5 to 14 years of age into our scientific activities. We have practiced 200 hours of teacher training and created dozens of workshops for adults, including educators and parents [14-16]. With school teachers we have developed new educational paths, integrating aspects of mathematics, physics, technology with attention to the use of language and various references to art. The experiments were well received to such an extent that for some teachers they became an opportunity to review their way of teaching: "The experience was very positive because it helped me make the children understand the concept of fraction. Their intervention (from the research group) definitely helped me and got me beyond my parameters. It was a good experience for me". Our interventions are also documented in two degree theses on primary education studies [22]. It seems to us that, after more than many years of direct commitment, the results achieved so far have been judged very promising by all the people involved. We are beginning to glimpse effective intervention models capable of adequately responding to the needs of the territories in which we operate. What have we learned? Firstly, we have understood that effective education proposals can only be developed with a profound effort of integration between experts in scientific disciplines, of mathematics, and the involvement of educators, psychologists, teachers, and families. The involvement of the educating communities represents the main long-term strategy and is essential for a conscious dissemination of science education on a large scale. Secondly, despite the data measuring educational poverty, we have seen something else. The emergence of scientific dialogue is possible in all socio-cultural contexts if additional support is provided, such as mediators including everyday language, local cultural experiences, and a phenomenological approach to the study of scientific disciplines [23]. This way of relating to people by resonance works because their self-confidence increases and helps them make sense of their knowledge. Physics education researchers need to interact with people and communicate the meaning of doing science: a huge challenge with inevitable uncertainties but with great satisfactions.

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