Action research: a new perspective in math and science education

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Abstract
This report is aimed to highlight the value of the action research methodology as a "catalyst for change" [1].
Our experience involved two Italian Secondary School, where small groups of students of the last two years, under the supervision of their teachers, respectively designed a drone powered by photovoltaic cells and an energy management system for classrooms, based on sensor networks and renewable energy sources.
The basic processes of action research, as in Lewin (1946), according to the well-known paradigm PLAN – ACT – OBSERVE – REFLECT, with an EVALUATION phase after each stage, in order to deciding eventual transitions to next stages, required the full involvement of all participating students. The teachers, in turn, played the role of actor-researchers in these experimental activities.
The overall vision consists in schools with enriched mindset, overlooking outside the classrooms, open to the territory, able to interact in wider horizons, in an European and worldwide outlook. Action research also involved a community of teachers as a framework for training and development of the didactic [2].
Students are the leading actors in the research action process, realized using the teaching strategies of Applied Problem Solving (APS) and the peer to peer education with seminars, lectures and workshops organized in different schools, but synergistically.
Finally, the projects were accepted in an international forum, SKYSEF, held in Japan in August 2015. SKYSEF's committee requires to the students a personal communication of their research, by scheduling parallel sessions of talks, divided by areas of interest, and poster sessions, adopting the practices of the official scientific conferences of the adult researchers.
After spending several months in implementing their projects, repeatedly bumping into unavoidable obstacles, the students had the singular and satisfying opportunity of sharing their findings and socializing with international peers and teachers. The inspiring atmosphere immediately created contributed to a very fluid negotiation of knowledge, to sharing of best practices, to the generation of new ideas and to the creation of promising contacts, as it would be desirable for any educational activity in general and definitely for science.

1. Introduction
Among various studies about the action research in Physics, for an instance [3], [4] and [5], the contribution in [6], although it dates back about twenty years, inspired our work. Feldman ‘s central ideas are resumed in the sentence “The model of action research that I used is a form of collaborative action research. “… practitioners working together to take actions within their situations in order to improve their practice and to come to a better understanding of that practice… groups of teachers working together... In using the term research, I begin with Stenhouse's definition, systematic, critical inquiry made public. And by action, I mean that there is an assumption in action research that a good way, if not the best way, to come to a better understanding of a complex system… is to take action within that system and pay close attention to the results of taking those actions.”
Our experience of action research is based on two parallel study paths on Physics, described in the following.
The first path is on Modern Physics. After some interactive theoretic lessons, a group of student started the laboratory activities to explore in practice some models studied before. The students came up with the idea of building a drone, which could take advantage of the energy coming from the light. This idea was immediately considered interesting, because physicists just declared 2015 the year of light.

The second path is on Energy. The students from Poggiomarino were involved in a study on smart grids and this topic gave rise to the idea of finding a way to rationalize energy use in the classrooms and to manage the lighting, heating and air circulation, making study environment comfortable. The project was based on the control operated by one of the newest technological tools, Raspberry Pi, and oriented to exploiting renewable energy sources, in particular photovoltaic, piezo-electric, pedal-powered or wind-powered generators.
The projects began with a careful and thorough analysis of the needs, the available resources and expected results. All students participated in the design actively and with strong motivation, sharing each other's hypotheses, developing each step with caution and in a systematic way, using resources rationally, considering both processes and products of the activities.
Nevertheless, it was always hold a holistic approach to the problem, trying to pay attention to all aspects, cognitive and non-cognitive, in the perspective of a school that looks out of the classrooms, open to the territory, able to interact in a wide horizon.

2. Light energy for a drone

For the construction of the drone it was essential an in-depth study on the materials to be used to optimize the flight; after a comparative analysis of three materials, the choice fell on the carbon fiber. In the graph below, in fact, it can be seen that the time of flight of the drone equipped with panels made by carbon fiber is greater than the time of flight of a drone equipped with panels PVC as well as greater than the time of flight of a drone without photovoltaic cells on it.

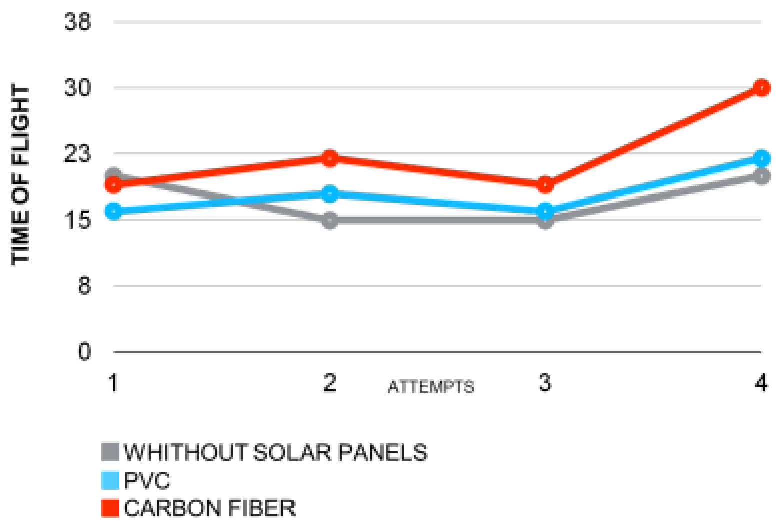

Figure 1:Time of flight of the drone in four attempts and with respect to building materials of the photovoltaic panels

Using the latest monocrystalline solar panels a 45%-50% longer autonomy can be achieved.
Another problem that the students had to face over the lifetime of the project was the placement of solar cells, because it could depend on the aerodynamics of the drone. It was established to position the solar cells of this prototype as in the figure 2, arranging six cells in parallel on each wing. It is thought, in a subsequent development, to mount le solar cells directly on the axes on which mounted propellers and possibly adjustable either manually or electrically ds so make the most of solar energy.

Figure 2 Position setting of the solar cells on the drone

3. Smart energy in the classrooms

Light and heat have a heterogeneous distribution in the different zones of the school building. A group of ten next to last year students of Scientific High School, concerned about the protection of the precious resources of the Earth and interested in the health protection in the school, decided to spend a wide time slice in their school year to implement a monitoring and controlling system for the classroom's environment. This research consisted in a detailed analysis of the energy demand of our school in order to rationalize the energy flows and to introduce energy-saving equipment and different types of renewable energy. To achieve this purpose, some experiments, based on sensor networks, were designed and performed, to detect the evolution over time of temperature, humidity and light in strategic points of the classrooms

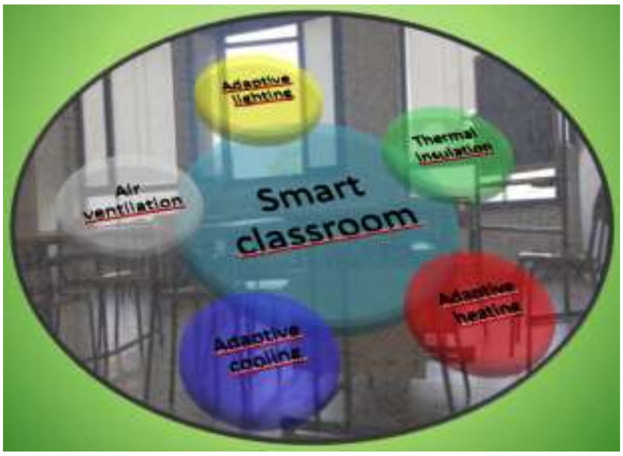

Figure 3: Schematic overview of the energy control system

The time series drawn from the monitoring, properly processed, indicated when and how it is really needed supplying energy, which can be directly supplied by natural sources or by cheap and light storage devices. Comparing the smart arrangement vs. the traditional grid, we got amazing results.
So the hope for the future is to foster healthy learning environments and optimal working conditions for students and teachers without overlooking the global environmental issues.

4. Action research and the SKYSEF experience

The basic processes of action research, as in [7],[8], according to the well-known paradigm PLAN – ACT – OBSERVE – REFLECT, with an EVALUATION phase after each stage, in order to deciding eventual transitions to next stages, required the full involvement of all participating students. The teachers, in turn, played the role of actor-researchers in these experimental activities.
Action research also involved a community of teachers as a framework for training and development of the didactic [2],[9].

The action research methodological approach was based on problem solving in order to identify solutions to the problem that, in most cases, are already in the problem although they are well hidden. Our experiment was an applied action research, because students learn more effectively from the things they do, so why waste time merely reading and studying theories and observing dummy examples when it can be possible to work directly on real problems? As Confucius said: “I hear and I forget. I see and I remember. I do and I understand.”

In a skills based learning it is necessary to reflect, think, become aware of the actions (learning by doing). This is likely practicable only going beyond the simple observation of phenomena [10].

The observation without an educational design, indeed, does not generate skills and simply working with artefacts, without reflection, does not generate skills.

method going beyond the transmission model and led to a shift from learning by doing to learning by thinking., without reflection, does not generate skills. It is therefore required to implement a teaching method which goes beyond the transmission model and brings to a shift from learning by doing to learning by thinking.

Through the action research, a mechanisms related to emotional intelligence [11] have been activated in the students, greatly improving their motivation to study, as well as the ability to discover the true and deep reason leading to action and empathy, i.e. the ability to get along with others, trying to understand the dynamics between them.

It was established between teachers and learners a stream of consciousness that made it possible to "live the act (of learning) itself, in the flow of pleasant emotions that provokes action, fully immersed in the situation" [12]. Being able to "tune" with a stream of consciousness allowed then to make a learning process more engaging and effective, fully realizing the "team-building" concept.

The APS methodology was integrated with peer education because it relies on a natural process of transfer of knowledge, emotions and experiences among members of the group; peer education has set in motion an extensive process of communication characterized by an intense and strong attitude for research, authenticity and harmony between the subjects involved

Students became agents of their development and their education, not mere receptors of contenst, values and experiences transferred by an experienced professional. This occurred by comparing different points of view, by exchanging ideas, by analyzing problems and possible solutions, in a dynamic between peers who did not rule out the possibility of seeking cooperation and support to experts.

Finally, the projects were accepted in an international forum, SKYSEF, held in Japan in August 2015. SKYSEF’s committee allows to the students to have a personal communication of their research, by scheduling parallel sessions of talks, divided by areas of interest, Energy, Environment, Biodiversity, and poster sessions, assuming the practices of the official scientific conferences of the adult researchers.

After spending several months in implementing their projects, repeatedly bumping into unavoidable obstacles, the students had the singular and satisfying opportunity of sharing their findings and socializing with international peers and teachers. The inspiring atmosphere immediately created contributed to a very fluid negotiation of knowledge, to sharing of best practices, to the generation of new ideas and to the creation of promising contacts, as it would be desirable for any educational activity in general and definitely for science.

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