Re-making Classroom Borders with TINKERING Approach

Alden Dochshanov[1], Michela Tramonti[1,2]

Abstract

Nowadays, the general understanding of hi-end technologies progress is essentially referred to IT-industry, but the further progress in technology, e.g. in nanotechnologies, are based on a continuous fusion of different branches of modern science. Thus, inter-, multi-, and trans-disciplinarity is a must to consider issue.

In addition, given a tremendous level of modern technologies we possess already, one may reasonably foresee that to pave a way towards more advanced technologies a solid knowledge may be just a partial prerequisite. Therefore, creativity, synthesis and imagination, capacity to build something new using the pieces already available come into play. In such an endeavour, tinkering, as a relatively new approach in a learning curriculum, may be of extreme practical usefulness.

In this context, the research intends to test an innovative learning setting and to design pedagogical-didactic tools based on "tinkering approach" in science education to be used outside the classroom. The learning path will be constructed on the base of the results achieved from an analysis on the use of informal activities in science education taking into account gender and geographical differences, and socio-economically disadvantaged groups by allowing these people to be close to science world and to live in an innovative way.

Tinkering methodology enables learners to understand, on their own, science by investigating tools, materials and exploring questions in which they are interested in. It is suitable for teaching and learning STEM subjects offering a wealth of opportunities for thinking through "making". Both "tinkering" and "making" support the development of the capacity for an innovative problem solving by engaging learners in hands-on and creative building projects combining science, technology, engineering and math subjects. This can ensure not only a variety of skills and mindsets, generally used in the classroom, but by supporting students to deal with engineered pieces of actual technology, treating those as tangible, manageable and adjustable objects according to their tasks' needs, the approach, thus, intends to prepare learners for life and work in the real world.

Keywords: *STEM education, learning by doing, inquiry-based learning, technology-enhanced learning;*

1. Introduction

The progress of science and technology achieved so far poses the challenging prerequisites to the future scientists as well as to the level of general public education in science. The background required for entering a scientific/research activity from one side and the conceptual coverage of the principles lying behind the modern science and technology are those bases that determine the level of professional and social activity of scientists and ordinary citizens.

The awareness of these basic principles for all citizens, independently of their professional needs, should be considered as an element of human culture. The last, if adequately grasped, substantially reinforces their potential in terms of employability and competitiveness.

In this context, science education has always to be seen from an updated perspective. Ubiquitous availability of information resources today inevitably poses a corresponding framework of mindset and skills to follow.

Given the rates of scientific information growth, the development of mental flexibility and multiperspectivity, enabling people to acquire and apply an adequate knowledge in a continuous fashion, has already become essential.

This, in turn, permits every citizen to deal with social issues, requiring scientific knowledge, for contributing into the sustainable growing of a society on a common welfare base.

Therefore, science education, dealing with sharing science content and processes among people who are not connected strictly to the scientific community, is a central part of the development of our society. In this aspect, the creation of a strong bond between the traditional scientific subjects, namely biology, chemistry and physics, and social science (e.g. pedagogy) becomes crucial for the

[1] EU-Track, Italy
[2] IMI - Bulgarian Academy of Science, Bulgaria

development of specific skills needed to cope with international challenges, such as globalization, resource exploitation and human aging [1].
Moreover, given the complexity of the modern science, e.g. nanotechnologies, where some 85% of research today is multidisciplinary [2], science education by providing the tools which reflect current trends in the forefront of research, can essentially promote social, economical and sustainable development in any nation. Actually, a strategy pointing towards a multidisciplinary approach may favor the acquisition of cross competences, reinforce the attitude towards the scientific method from different paths, widen the student's view from different perspectives and, as a result, to push forward the emergence of the key-concepts shared across the different viewpoints [3]. For example, a physicist with some knowledge of electronics after a short training in the modern technology, can become an electronic technician [4].
However, scientific and technological culture in Europe, despite the excellence in some countries, should be still promoted. This is confirmed by the results derived from national and international surveys, such as TIMMS Advanced (Trends in International Mathematics and Science Study Advanced) and PISA (Program for International Student Assessment), administrated to students in order to verify their academic performances and to understand their difficulties, especially related to the study of science and technology.
Actually, student engagement to scientific and technological studies is decreasing or at least has not been developed as fast as expected. This lack of interest in science often appears at school time when students have to make a decision on future professional career [5] [6].

2. Re-making classroom borders in a creative education setting

A multidisciplinary character of the current front-edge research in the fields of nanotechnologies [2] and nanobioelectronics challenges both researcher and the student to learn and think continuously outside of their zones of comfort and training [7]. According to MIT's white paper on convergence, which involves the merger of life, physical and engineering sciences into a unified whole due to true disciplinary integration will generate new pathways and opportunities for scientific and technological advancement.
It logically follows that new adapted methodological approaches contributing to a gradual acquisition of a flexible, multidisciplinary, holistic mindset for students of different age groups are urgently required.
In this framework, an innovative learning setting including pedagogical-didactic tools based on "tinkering approach" is needed in order to increase science education skills in a multidisciplinary vision inside and outside the classrooms.
The approach proposed reinforces the concept of “science education” understood as a two-way process where a set of knowledge, values, habits and ways of interacting with the environment/learner context, in which they are immersed, is exchanged and shared among learners.
Through the development of learning activities outside the classroom a spontaneous learning process is favoured with the aim to form habits, values, experiences and skills outside the institutions set up specifically for that purpose [8].
According to this definition, informal science education can occur anywhere: e.g. in a museum where scientists can plan and run public programs or teachers' sessions, or through television and radio and in any organization that deals with educational science content [9]. The activities to be carried out may include working directly with the public, creating and managing education science content or working on policy.
However, this research assumption is based on the idea of a certain continuity in the transition from formal to informal education activities by creating and introducing new concepts into the education process and by making it closer to the individual and, in general, society needs [10].
The approach, described in this paper, is centred on the “making”, which emphasizes "learning by doing", often fitted into a social environment. The main reason is that the current level of technological development (e.g. gadgets, Smartphone etc.), would have been inconceivable without cross-cutting achievements of material sciences, microelectronics and programming.
In addition, seen from an average consumer point of view, the Smartphone is considered more as a communication/recreation tool the full potential functionality of which, especially, from a young generation point of view, still remains hidden.
Therefore, to promote a conscious use of a modern technology by youth, to help them in a selective covering of the variety of related scientific topics underlying it in a more effective and illustrative way, to promote the perception of a STEM issues as something manageable, directly related to real physical objects (including their own Smartphone) by stimulating their courage in terms of creativity, independent thinking and continual curiosity, "Tinkering approach" is proposed. The idea is to shift the

mindset of adolescents from a passive following and consuming of hi-tech products, towards their conscious and creative use through the conceptual understanding of the underlying principles and basic skills development.

2.1 "Tinkering" for a multidisciplinary science education

Literally, to "tinker" is to make small changes in something, or to repair or improve it. Only recently "tinkering" has been introduced into the educational sector as a potential guide of creativity, excitement and innovation in science education.
Thanks to its inter- and multi disciplinarity, it provides learners (of any age) with effective means to explore STEM (Science, Technology, Engineering, Math) concepts, practices, methods and phenomena. This approach, usually, combine the high and low technological tools of science with a strong aesthetic aspect, supporting learner (from children to adults) self expression. It can encompass a very wide range of activities from traditional hobbies and crafts to the use of robotics,
Arduino and 3D printing. Actually, considering today's technology point of view and taking into account the enormous potential of such platforms as e.g. Arduino, Raspberry Pi, together with the relevant auxiliary electronic components, both new and recycled ones, the overall complexity of problems and topics that might be covered, represents in many respects a flexible and conceptually unlimited
framework for methodological exploration. Consequently, when applied to a learning process, tinkering represents a core part of a hands-on trial and error-based process that rewards persistence, creativity, resourcefulness and self-sufficiency.
Moreover, if properly designed, every tinkering lesson may become an essential auxiliary tool to introduce/reinforce concepts covered within the classical curricula in electronics, mechatronics, robotics and coding classes for a wide range of age categories of students.
Tinkering training path enables learners to understand, on their own, science by investigating tools, materials and exploring questions in which they are interested in. As a result, it is suitable for teaching and learning STEM subjects offering a wealth of opportunities for thinking through "making". Both "tinkering" and "making" support the development of the capacity for an innovative problem solving by engaging learners in hands-on and creative building projects combining science, technology, engineering and math subjects. In particular, "tinkering" is related to the development engagement among learners and "making" is to teach skills and knowledge. These two elements in the learning process develop "innovation" by providing opportunities for learners to show how they make concepts, how they manage an appropriate use of tools and how to find creative solutions to problems [11] [12].
In this framework, "tinkering" and "making" breaks down the learning objectives into several components and, consequently, learners have many chances to build on skills as they acquire and improve them.
This can ensure not only a variety of skills and mindsets, generally used in the classroom, but by supporting students to deal with engineered pieces of actual technology, treating those as tangible, manageable and adjustable objects according to their tasks' needs, the approach, thus, intends to prepare learners for life and work in the real world.
As one of the corner-stones of the tinkering approach is namely recycling (recovering and re use of engineered pieces by disassembling of obsolete computers, printers etc.) with subsequent more sophisticated combination of recycled materials with low-cost open platforms to enhance the ecological impact and turn the re-use of a recycled material into a constructive education-oriented way.
To give the concrete introductory "tinkering" project example, the clapping-driven fan demonstration can be offered as is shown in the Figure no.1.

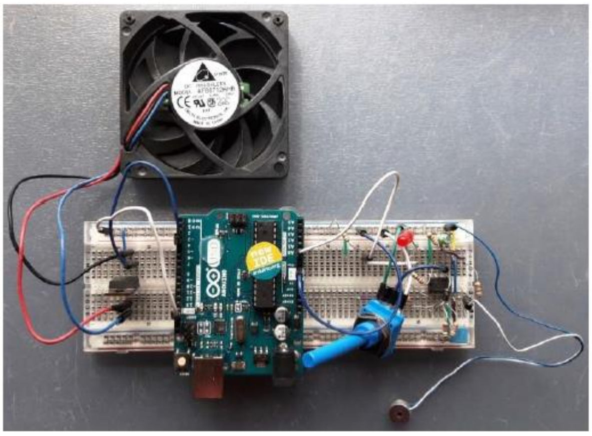

Fig. 1. An example of Tinkering project (clapping-driven fan demonstration)

The working principle is the conversion of the number of the claps detected into the corresponding velocity (3-level) of a cooler fan. As one can see, the variety of the subjects covered in a single example represents a rich fusion of the concepts and topics normally covered in electronics course curricula.

In particular, they include: operational amplifiers (as a stabilized amplifier and comparator); diodes as components for peak detectors; analog to digital (ADC) conversion and vice versa (DAC); metal-oxide semiconductor field-effect transistor (MOSFET) application; pulse-width modulation (PWM); microcontrollers' programming. Another point to consider here is the use of both recycled components (in this case DC brushless cooler fan with the market value of ~8 USD and microphone – are recovered for free from an old computer), and discrete components operational amplifier, resistors, diodes, transistors. Furthermore, the application of Arduino platform essentially facilitates the claps counting and transforms them into pulse-width-modulation signal to control the fan.

To generalize, the approach proposed may be represented in the following diagram (Fig. 2):

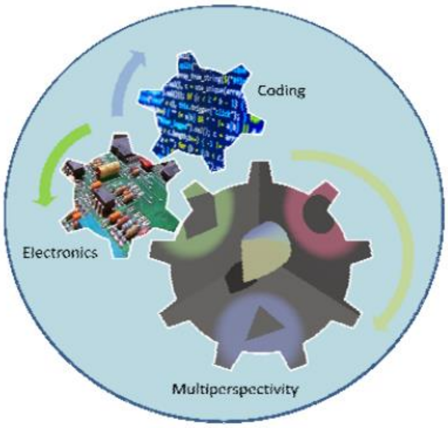

Fig. 2. Tinkering project as unifying combination of electronics, coding and multiperspectivity

Since multidisciplinarity and multiperspectivity due to the diversity of the objects involved (different components: diodes, transistors, microcontrollers), the variety of the activities and skills that supposed to be performed and mastered are in the core of the project's tinkering vision.

3. Conclusion

As a result, the introduction of "Tinkering approach", considered as a tool for the continuum between formal and informal education, learners are provided with an open-ended opportunity to do research, develop empathy, create questions and reinforce their motivation during the learning process favoring their sustained engagement during the educational activities in a collaborative setting.

Moreover, "Tinkering" represents an adequate approach to bring science and technology, without exception, to youth and adults, in particular, at risk of social exclusion, by inspiring and preparing them for the challenges of the new millennium. This will contribute, in long term, also to economic well-being.

References

[1] European Commission Communication, *EUROPE 2020 – A strategy for smart, sustainable and inclusive growth*, Brussels, 3.3.3010.
[2] Milojević, S., *Multidisciplinary cognitive content of nanoscience and nanotechnol*ogy, <<Journal of Nanoparticle Research>>, 14(1), 2012.
[3] Iadonisi, G., *Introduction to Solid State Physics and Crystalline Nanostructures*, Springer, 2014.
[4] Aina, J.K., *The Economic importance of conductor, semiconductor and insulator, 2012.* Retrieved from http://www.amazines.com/article_detail.cfm?articleid=4246828 in 02/08/2017.
[5] Osborne, J., & Dillon, J., *Science education in Europe: Critical reflections* (A report to the Nuffield Foundation), 2008. Retrieved from http://www.nuffieldfoundation.org/sites/default/files/Sci_Ed_in_Europe_Report_Final.pdf.
[6] Potvin, P., Hasni, A., *Interest, motivation and attitude towards science and technology at K-12 levels: a systematic review of 12 years of educational research*, <<Studies in Science education>>, Vol. 50, No. 1, Taylor & Francis, 2014, pp. 85-129.
[7] Offenhäusser, A., R. Rinaldi, *Nanobioelectronics - for Electronics, Biology, and Medicine*, Springer New York, 2009.
[8] Didactic Encyclopedia, *What is the meaning of Informal education? Concept, Definition of Informal education*, The Editors of Didactic Encyclopedia, 2013. Retrieved from https://edukalife.blogspot.it/2013/01/definition-of-informal-education.html in 02/08/2017
[9] Bernstein, R., *Educating outside the classroom*, Retrieved from Bevan, B., *The promise and the promises of Making in science education*, <<Studies in Science>>, 2015.
[10] Zaki C., *Formal, non-formal and informal education: concepts/applicability*, published in “Cooperative Networks in Physics Education - Conference Proceedings 173”, American Institute of Physics, New York, 1988, pp. 300-31.
[11] Dweck, C. S., *Mindset: The new psychology of success*, New York: Random House, 2006.
[12] Dweck, C. S., *Mindset: How you can fulfill your potential*, Constable & Robinson Limited, 2012.