"TINKERING" AS LEARNING REINFORCEMENT TOWARDS MULTIDISCIPLINARITY IN RESEARCH-ORIENTED EDUCATION

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Abstract

The drastic technological development we facing today has led to the pervasiveness of low-cost platforms with inherent tremendous functionality from one side and ease of use from the other. As consequence, the ubiquitous availability of these instruments has contributed, as we see it, to the reformation of the term of "tinkering". A cursory glance at a list of videos on YouTube to the query: "tinkering" or "arduino-based projects", might even give an idea of a certain subculture formation. Moreover, the variety of the free applied engineering apps, which may turn a smartphone into an oscilloscope or a signal generator for example, are to consider as well due to their obvious potential utility in research-oriented education. Together they form an extremely flexible, universal and potentially fruitful environment to keep STEM curriculum updated and represent a huge source for pedagogical ideas renewal and adjusting according to the state-of-the-art in emerging technologies. Thus, we argue that an appropriate mode to think and act in a "tinker-way", to orient oneself within the flow of today's technical possibilities become a relevant issue for both parties: educators and students. Undoubtedly, the specificity of scientific and research-oriented education implies a compulsory basic curricula to follow. The last is absolutely crucial to the formation of a solid professional mindset in every major. But to render theoretical knowledge active, problem- and application oriented, more effective in the face of different multidisciplinary contexts, of course, is not an easy task. On that basis, we discuss the potentiality of tinkering as an auxiliary tool in such an endeavor. In particular, first, by re-determining tinkering in the context of STEM education, we that this phenomena, if adequately adopted, may be of significant value and profit. And secondly, on the example of several projects developed, we discuss the aspects of multidisciplinary potential of this approach which, unfortunately, is still insufficiently apparent, and therefore underestimated.

Keywords: STEM Education, Tinkering, open platforms, apps.

1 INTRODUCTION

Being a part of the "Maker Movement" which have begun in 2005 in Silicon Valley [1], tinkering, as an educative approach, emphasizes creative and improvisational problem-solving [2]. Today the topic have reasonably attracted the attention of educators [3-7] and policy makers [8]. Being acknowledged for its creativity stimulating nature, the approach is argued to be a vehicle to gain knowledge and skills profitable for engineering, design and science [9].

The boom of the open-platform based projects, from the other side, such as Arduino [10], Raspberry Pi [11], Open-BCI [12] as a logical step of evolutionary development of technologies provides an immense range of functional complexity never thought before. The concept of "open" platform enhances their impact in terms of associated communities formed, the way they interact [13-15], and the complexity of the projects they share [16-18].

In addition, the diversity of mobile apps available in PlayStore, e.g. Signal Generator (from Kewlsoft) [19], Every Circuit [20], represents another source of huge educative potential, that enables one to possess a direct access to the advanced functional complexity of a hardware generator of a palm size, which may easily be coupled to an external circuitry [21, 22], or enhance the intuitive understanding of electronic circuitry via animation [23].

With all these instruments at disposal, future engineer, to explore the most of them, is supposed to be proficient both in hardware and software design by default. But when it comes to the scientific education, especially regarding Nanotechnologies, the quality of core vision to transmit to the future Nanotechnologist becomes a bit complicated. In particular, if one considers Nanotechnologies as the platform to produce the single hardware elements [24, 25] and, as consequence, the electronics of

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tomorrow [26], the student, in such a perspective, has to be aware of both the issues related to material science and basic principles of electronics, including hardware logic at different scales (e.g. single transistor and operational amplifier-based circuitry).

To provide such a vision, the combination of two points is proposed: *multidisciplinary* and *evolutionary* approaches. While the first facilitates interaction with colleagues of other professional fields and enhances vision for ideas and methods exchange [27], the second one may be considered as an auxiliary tool to trick a student into the evolving continuity of engineering ideas and their interplay at different stages.

The article, on the example of a simple tinkering-based project, shows how a combined vision of multidisciplinary and evolution approaches may be introduced through “thoughtful” tinkering. The last, as the results will show, is to be preferably used instead of iterative, mechanistic and therefore less efficient making-based tinkering.

2 METHODOLOGY

The core of the technique is to provide a student with a complex vision of different aspects of modern electronics combined in a single project. As an example, the clapper counter-driven fan has been proposed. The project (see Fig. 1) is the combination of the online-tutorials [28-30] with Arduino platform [31]. 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.

As a result, student receives a concentrated piece of different topics combined together in a contextualized fashion, i.e. the concrete function of system, the transformation of the number of the claps detected (input) into the speed of the fan (output). Such an approach, according to author, triggers significantly an intuitive understanding of different components of the system both in terms of their independent behavior, to meet the requirements of the overall task (as subsystems in this case), and, as consequence, the system as a whole.

From the other side, the combination of discrete elements and integrated circuits permits one to gain unconsciously the insight into the evolving continuity of engineering ideas and their interplay. This point is of ultimate importance, especially when dealing with nanotechnologies. Because of the tremendous growth of information and IT-based technologies, artificial intelligence in particular, may unreasonably shift the attention of future nanotechnologist towards readily available hardware solutions only. In this context, programming transforms into a sort of “soft soldering iron”, and the direct contact with hardware (analog in particular) and its logic at the physical level is inevitably getting lost.

Finally, the range of the objects and topics covered in a single project enables one to become more flexible in terms of their combination and, as result, to acquire, if not a purely multidisciplinary vision, a predisposition to it, which, in turn, is of fundamental importance for the future nanotechnologist.

Taken together, approaches described above in the given context compose a basis of what the author would call as “thoughtful tinkering”, an approach which is aimed at diversifying the concept of tinkering as a maker activity only.

3 RESULTS

The methodology described before has been applied within the framework of the Laboratory classes in Robotics of the Master course in Nanotechnologies at Sapienza University of Rome. It is appropriate to mention that the students following the course are from different majors, e.g. mechanical engineering and chemical engineering.

As one can see (Fig. 2) from the project developed by students with mechanical engineering background, which substantially represent a couple of DC motors driven in a multimode way via the computer interface through Arduino platform, the idea of connection of different kinds of circuitry and hardware has been successfully understood and realized. Important to underline, that from the view of both multidisciplinary and evolutionary approaches the project developed fits perfectly well with the variety of skills involved (programming, hardware design) – multidisciplinary component, and elements used (microcontroller, MOSFETs, LEDs, potentiometer) – evolutionary component.

It is believed that such kind of projects, being developed routinely and reflected upon(!), may contribute to the gradual acquisition of thoughtful tinkering vision, which may be of essential use in the future career of engineer.

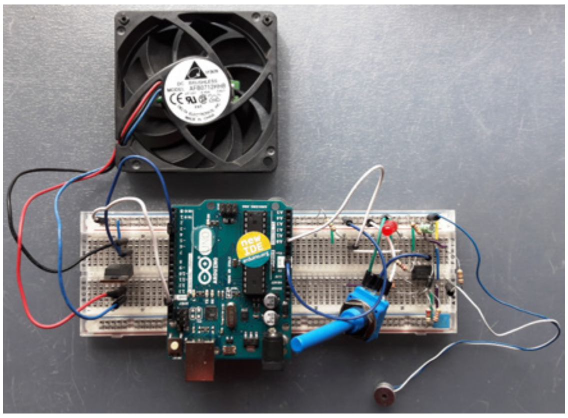

Figure 1. Clapper counter-driven fan.

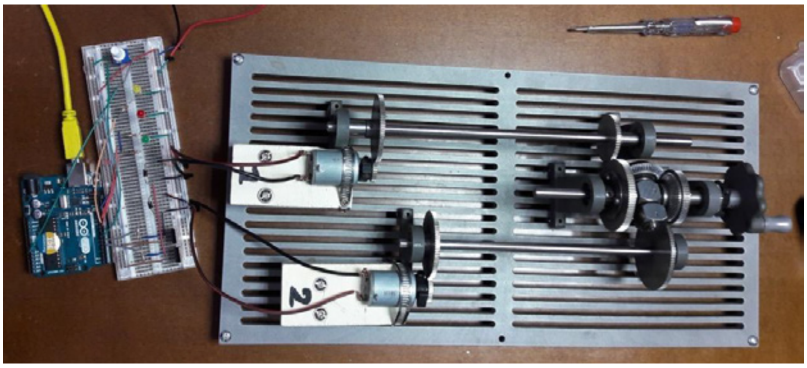

Figure 2. An example of a project developed by students (credits: Giorgio Parisi, Matteo Passafiume).

4 CONCLUSIONS

The convergence of non-invasive Brain Computer Interfaces, advanced biosensors and processing algorithms has already been announced by Facebook to enable a keyboardless typing directly from the brain [32]. From the other side, nanotechnologies, as a platform of further advancements in science and technology, is intimately tied with the current technologies (i.e. micro- nanofabricated tools [33-36]). Therefore, for the future nanotechnology engineering specialist is important and even crucial, to be aware of not only the principles behind the current state of the art, but to posses the clear vision of *evolutionary continuity* of ideas lead to it. In addition, due to inherently universal character of nanotechnologies applications, that have already lead to a qualitatively new tools for medicine [37-39] [40], [41] or a new kind of electronics even [42] *multidisciplinary vision* is of undoubted value as well.

Author believes that to deal with such an endeavour, tinkering and thoughtful tinkering, in particular, may represent a limitless field of enormous potential for didactical exploration as an auxiliary methodological tool.

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