MULTIDISCIPLINARY ROADMAP FOR STEM EDUCATION: A CASE STUDY

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Abstract

The ubiquitous penetration of technologies into our everyday life may be treated as something inescapable and natural. The ways we interact, get updated, organized have been essentially influenced and facilitated by Smartphones, social networks and others ways of mobile communication. In addition, the use of specialized applications can help people to reduce significantly the times of optimization and development of virtually any imaginable consumer-product from a scratch. However, the continuous exponential growth of available information has already triggered an up-rising demand on data-scientists, supposed to organize and extract the statistically valid outcomes for the present and future use.

From the other side, the request to increase the collaboration among different scientific fields led people towards an interdisciplinary and multidisciplinary approach, both terms of actual research and the student education. One example may be provided by nanoscience branch, one of the central research trends of today's research and development. In fact, being considered as a multidisciplinary one, where qualitatively new steps are feasible on the base of a close interdisciplinary collaboration, the field keeps unveiling the fundamental nanometer limit of matter due to the intense worldwide research, where classical and quantum concepts merge. Worth-noting, that nano-research, in addition to a close interaction of different majors, requires individuals' effort in terms of acquisition of a certain mindset as well, for which neither continual (classical) nor discrete (atomic) considerations are absolutely prevailing.

Therefore, considering both mentioned aspects, from one side, the necessity of dealing with a huge amount of data and from the other side, a flexibility of individuals' mindset in terms of holistic/prone to a synthesis view acquisition, the student education will be more effective taking into account the contextualization, multiperspectivity and interdisciplinary of the learning process at every school level: from primary school to higher education.

In this context, the article aims to show how such a methodology can be realized through a research experience based on robotics by using Arduino platform.

Keywords: STEM education, learning by doing, problem solving, inquiry-based learning, technology-enhanced learning, Arduino platform.

1 INTRODUCTION

The continuous prevalence of IT industry for the modern society, despite a certain ambiguity in the worldwide perspective, e.g. [1], and further advancements in artificial intelligence [2], big data processing algorithms [3], [4] are already well established and mature topics the research community tackling with. In addition, the majors as data analysts [5] and data scrapers [6] have already started to spread widely, which by itself may carry an enormous potential in terms of multidisciplinarity [7, 8] of STEM education [9].

All pervasiveness of information resources and open platforms enables one to discover independently how a certain simple electronics project, for example, could be developed. In fact, we live in a time, when just a pure inquiry from a part of a curious student is enough for the knowledge to be transferred and contextualized through the number of examples elaborated and uploaded into the public domain [10].

From the other side, especially when one is dealing with engineering framework, the variety of explicit and implicit skills required may seem not so uniquely defined. Coding, electronics, Computer Algebra Systems, Computer Aided Design and Engineering software substantially are the things available to everyone, possessing the desire to learn and discover how this arsenal could be adequately applied. In addition, engineer, as a person who predestined to correlate the theoretical ambitions with

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technological constraints, in a large part needs to nurture a great deal of intuition and ingenuity, based on a common sense and thoughtful working experience [11].

As Nelson [12] reasonably remarks: "I began to realize that while each discipline carries its immense load of experimental and theoretical machinery, still the headwaters of these rivers are manageable, and come from a common spring, a handful of simple, general ideas". Robotics engineering, viewed from this perspective, represents the particular case. Being originally derived from the domain of classical science, mainly mechanics [13, 14], now has a lot to do with electricity not only in terms of trivial actuation and sensing (e.g. mechatronics), but artificial intelligence [15], bionics [16] and last but not least micro [17-20], and nano-sized grippers [21], supposed to be the prototypes of grippers of the so-called nano-bots [22]. This immense range of functionality is mainly derived from the fact that the main material of these microsystems is silicon, with all those consequences in terms of miniaturization capacity and functionality inherited from micro- and nanoelectronics industry.

Thus, educational robotics can be regarded as a mean of insightful and harmonic parallel way of introduction to coding, basics of electronics and mechanics converged around the robo-project to develop. In fact, it carries all those fundamental characteristics, required of a modern engineer, who is interested to enter the field of nanotechnologies, where, as it has already been discussed earlier, multidisciplinarity, multiperspectivity and perceptual multifocality are among the primary prerequisites to succeed.

2 METHODOLOGY

With the years to come, the range and the quality of goods available exceedingly prevails our expectations, for example, a single smartphone offers to a customer a spectacular range functional versatility, capable to possess entirely and even dominate our everyday lives [23], [24]. Furthermore, the further development in the sphere of IT technologies [25], which may be seen as the dominant one, risks to inevitably expand the gap between the solid-state physics, which, is being multidisciplinary itself and generally considered as difficult, still lies at the core of the material science.

Fortunately, open platforms, as Arduino, with all the their broad communities, permit almost to everyone to enter the fascinating and exciting world of tinkering with Arduino components, to feel free to discover an immense world of electronic components, previously considered as something absolutely difficult and over-schematic. This *fact represents that missing link, which connects straightforwardly the relatively old past of electronics with all those modern variety of integrated circuits and other components*, stimulating the (see. Fig. 1) inquiry-based learning issue latently manner as well.

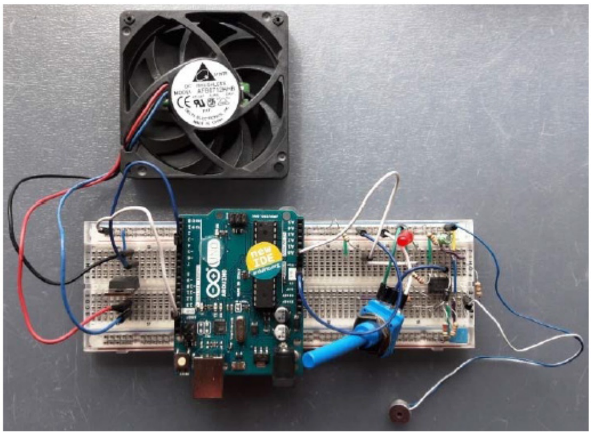

Figure 1. Arduino based project clapper-driven fan.

The methodology used in this approach was thoroughly described in ref. [26]. 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, namely to transform 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 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 situation, 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, but a predisposition to it, which, in turn, is of fundamental importance for the future nanotechnologist.

2.1 Robo-1

Following the methodology described above, the project called "Robo-1" has been developed (Fig.2). The idea lying behind is to introduce children of 6-12 years old to the principles of logical reasoning, and elementary sequencing development.

The robot follows the track preprogrammed previously, using the corresponding knobs Left, Right, Forward (see Fig. 2a), and triggered to move with the Start knob. When ready for new commands set inserted, the indicator is green, during the sequence insertion – blue, active state of execution is marked as red. The model uses two dc motors controlled through the standard H-bridge (L293C).

The general algorithm is subdivided into two phases: formation of the "governing string", and its first-input-first output (FIFO) – reading. "Governing string formation" – is a sort of sequence, corresponding to the inputs from governing knobs: every knob pressed forms the corresponding change in the string. Obviously, the minimum knobs necessary for the system for work is 1.

To give an example: the serial input of the knobs "Left", "Right", "Right", "Forward", "Left", "Start" will form the LRRFL governing string, which at the phase of execution (following immediately after "Start" button is pressed) will bring the robot to move correspondingly to the left, right, right, forward and left.

As one can see, the idea that stands behind is simple enough to be realized with an active support and inquiry of children. The basic piece used is the cardboard from of a mobile phone. Another crucial point is that the minimalistic character of the basic functions of the base Robo-1 presumes and encourages further advancements and enhancements in terms of accuracy, sensitivity, reaction to a particular types of external fields and agents (light, water, gas, magnetic field), and, what renders this instrument more attractive – are the intensities of the fields and their spatiotemporal interplay [27], [28].

Figure 2. The Robo-1 model developed on the base of the Arduino platform: a) top view with indicated control knobs and performance indicator; b) back view with the switch on-off knob; c) general view of the robot.

As one can see, the ideological trends imposed by a modern nanotechnological research, in particular a duet between multi-, transdisciplinarity and multiperspectivity, when adequately refracted and adopted, may bring far-sighted results. Not only in terms of a particular robotic project development, with enormous exploitation degrees of freedom by itself, but in the cultivation of the approach the actual serious scientific problems can be dealt with – reasonable data analysis and multidisciplinarity.

3 CONCLUSIONS

To proceed further the collaborative work of different majors is absolutely required, but to the researches continuing of possessing a sort of “continuous transdisciplinary” in research vision, when the solid knowledge of one’s field doesn’t represent an overwhelming obstacle. In addition, a researcher is always “fresh” enough in terms of a new information and experience acquisition and manipulation with. Moving only in this way, the real groundbreaking discoveries may become possible.

Therefore two points of view are proposed to be combined when dealing with multidisciplinary roadmap for STEM education: continual perception and awareness of technological solutions (such as Arduino platform where different pieces both discrete and integral can be easily combined for the scheme to work), and intrinsically multidisciplinary character of nanotechnologies, where the atomic ad continual worlds merge giving rise to a new properties of matter to be discovered.

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