Robotics for Teaching Creative Activities in Primary and Secondary Schools - a Case Study

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Abstract. The good development of modern societies requires a substantial fraction of the population, and in particular of workforces, to be somehow expert in scientific and technical areas. Furthermore traditional approaches in education have proven inadequate to ensure alone the evolution towards this ideal balance. A consensus has formed on this issue in advanced countries, with the combined effort of devoted volunteers, professionals open to cross-cultural influences and finally the support also of political people and the government. The current paper reports on a case in Western Switzerland where innovative and promising actions have been progressively set into place, in particular relying on robotics, for fostering novel changes in curricula for primary and secondary education. Some enthusiastic teachers, ready to consider the necessary reorientation, are offered graduate level, adjustment training, where woodworking and metal processing techniques are now complemented with new, basic yet effective skills in electronics and programming. Federal action will follow.

Keywords: Robotics, STEM, MINT, Education, Outreach, Creative activities, Primary and Secondary Schools, University curriculum, Electronics, Pedagogy.

1 Introduction

Long after the tribal nature of early times, current human societies appear as highly complex systems, featuring millions of specialized profiles allowing virtually billions of individuals to communicate and interact with each other, and ultimately, to contribute to the general well-being.

Even though much has been done through the ages, new challenges appear. For what concerns our modern societies, novel actions are required for technical and natural sciences, as well as information-related technologies [1-6]. Researchers in education have also found that pupil's attitude towards technology is a crucial

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element for long term success [e.g. 7]. In our community, we have also identified this problem and have already contributed in concrete terms to its solution, as presented in this paper and references. Hopefully this experience can be useful for others, and in the other direction, possible suggestions for improvement would be welcome.

In this paper, Section 2 discusses the current need in education for technical and natural sciences as well as information related technologies in early school years. Then our case involving Switzerland, and more specially its Western, French-speaking part, is presented in 3 sections, relating first to an initiative for the promotion of robotics at country level (Robot-CH, Section 3), then to an experimental initiative bringing together professionals in pedagogical education for the young age and technical and scientific experts in robotics (Section 4), and finally, in Section 5, a graduate course in the current curriculum of students in pedagogy, ultimately aiming at raising the interest of pupils of the primary and secondary school level for technical and natural sciences as well as information related technologies.

2 Changes in education for technical and natural sciences as well as information related technologies in early school years

Education has evolved through ages. This section first gives the broad image, a general overview, and then it focuses on the specific case of changes occurring in the context of school programs for creative activities.

2.1 The general view

Evidence exists that humans appeared on Earth on the order of a million year ago, so it took all that time to reach the world population of today, actually with most of the development appearing in the last centuries [e.g. Biraben, 8]. While in early times human communities were very small and sparsely distributed, today billions of individuals may communicate, interact with each other, and contribute to the global life, so building-up a powerful, intricate network of diverse capabilities and skills.

A particular challenge we consider in this paper relates to the fact that, for these human individuals, the time from fresh, undifferentiated birth state to maturity age, as an adult with specific profile (language, culture, professional skills, etc.), has remained quite similar, mostly in the 1 to 3 decade range.

Obviously, through ages the education challenge has been somehow successfully met until nowadays; at least to the point of bringing us here. While the early resources were consisting only of parents, families and tribes, through the ages, progressively, much more elaborated structures have been added: religious guidance, public education, professional schools, academic universities, etc.

Yet changes in education have often translated into societal crises, when only the proven shortcoming of previous approaches could lead to the new, necessary, tentative, and finally successful approaches.

Today the level and diversity of requirements in education not only increase but moreover changes accelerate. For example in the experience of one of the authors, i.e.

in a fraction of a lifetime, the classical framework for education has moved from quasi-religious school to public schools, to the contexts of continuing education, outreach, and finally workforce development; from the concept of multi-year classrooms to an organization where extended periods of time are individually allocated to students for personal work; even in academic courses, a strong evolution occurs, whereby ex-cathedra lectures on one hand seem to generalize to a scale where a massive number of students can attend online (re. MOOC – massive open online course) and on the other hand give place to interactive sessions and coaching activities.

In most modern, advanced societies, an adaptation problem has been identified in education, whereby some incentives should be given to young children so as to raise their interest in STEM disciplines (science, technology, engineering, and mathematics, e.g. [1,2] in USA, with an ultimate goal "of global leadership"), or similarly MINT (mathematics, information-related technologies, natural and technical sciences, e.g. [3-5] in Switzerland). Action is required for roughly the next 10 years, and a horizon line for results is lying somewhere within this 21st century (The situation may be different for UK, where pioneering work can be traced back for 30 years in terms of technology-oriented curriculum?). Inclusion of Arts has also been sometimes considered (re. "STEAM"), but the risk increases then of eroding otherwise more focused priorities.

Academic researchers agree of course with these political and governmental recommendations, being both, for some, at the origin of these considerations, and, for some others, on the side of an optimal implementation of this endeavor (e.g. for the French-speaking part of Switzerland [re. 6]).

The current paper precisely relates to the need of adaptation in technical and natural sciences as well as information-related technologies in this context, presenting the major aspects of our case, in the next three sections. But let us first review the changes typically occurring for the context of "creative activities" curriculum.

2.2 Changes occurring in the context of school programs for creative activities

The introduction of teaching for creative activities, focused on technology and innovation, is introduced during the discipline relating to creative and technical activities. The introduction of teaching for creative activities, focused on technology and innovation, is introduced during the discipline relating to creative and technical activities. In fact, the epistemology of the discipline of creative and technical activities is part of a dual relationship that is critical to understand before deciding on how it should be taught and how it should evolve.

First, the historical dimension highlights the fundamental elements conveyed by the teaching of manual and technical activities. The latter is meant to be a repository of manual instructions transmitted through technical, rigorous and precise actions. The relation to practice, intrinsic to this discipline, is characterized by the crafting of functional objects aiming at the acquisition of dexterity, precision, rigour and skill. For decades, these different facets, inherited from different professional bodies, were the exclusive points of its teaching.

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The second characteristic feature of the teaching of creative and technical activities comes from the way we teach this acquisition of precise and rigorous actions. The choice of objects and the sequence of planning through clearly defined stages, allow students to advance in the realisation of the object in a measured and controlled way. The way in which the instruction is organised, in the form of procedures carefully prepared by the teacher in advance, places students in the position of executor, performing the tasks assigned to them. This approach satisfies the need for organisation, speed and efficiency of production.

This dual relationship is explored in more details in the next two subsections, which relate respectively to creativity in production and innovation in design process.

Develop creativity to improve production. How can we reconcile a discipline based on the transmission of manual actions inherited from traditions with a complex multiform concept applied in an educational context aimed at producing quality objects? We hold to the following definition of creativity as "the ability to produce an expressible idea in an observable form or to realise a production that is both innovative and unexpected, adapted to the situation and (in some cases) considered to have some utility or value" (Bonnardel 2006, p. 21 [9]). This definition highlights the importance of the specific context in which objects are realised, as well as their usefulness and value. In an educational context that reconciles production with learning, we propose to introduce the activity of design as a creative process.

Design as a process towards innovative objects. The cognitive operations induced by design activities [10] lead students to enter into a contextualised creative process. Design requires identifying and analysing the problem and finding innovative and appropriate situations for realisation [11]. Design activities include the stages of creativity process and use divergent thinking, a key element in design phase, where the author/designer must abandon every day routine in order to explore the world of ideas and to propose innovative solutions [12]. Divergent thinking, underused in schools [12], is one of the key phases of the design activity. The selection of the ultimate idea must then factor in all the needs and constraints of the object. This requires convergent thinking and takes into account different subjective parameters. In this design phase, we can see the intervention of several transversal skills used in other disciplines. The task of innovation, combined with the constraints imposed by materials, as well as the implementation and functional use of the object, stimulate students and systematically teach them to anticipate. Notice that the current notions of "convergent" and "divergent" cognitive activities correspond well with the notions of abstraction and concretization in "MCS" model for cognitive sciences [13].

3 Robot-CH, for the promotion of robotics in Switzerland

In the study case we report, focusing on Western Switzerland, the convenient current adaptation of school curricula to modern requirements in the education of future

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citizens could benefit from the initiative of various innovators joining forces to create the Robot-CH association.

Robot-CH was created in 2002, with the goal of promoting robotics in Switzerland, in order to give a more formal character to an initiative that could be traced back to the year 2000 or even earlier in 1998, in relation with the organization of robotic competitions at the Swiss and European levels [14] (e.g. also Fig. 1 and [15-17]).

Fig. 1. Example of Swiss Eurobot competition and primary and secondary school contests (re. [15] for a video, or [16]). Overview (*left*) and winners (*right*) ; on the right we can see FLL-typed contest tables for pupils, as well as three of the robots especially developed for Eurobot.

The aim is to establish at the level of Switzerland a platform where all important associations and organizations of the robotic domain, research and education institutes, public institutions as well as specialists and engineers could meet and exchange. Robot-CH has first developed, through robotic contests, outreach activities towards general public and the promotion of robotic jobs and world for the youth. Then additional activities have developed on professional and education domains.

In particular Robot-CH has coordinated, at Swiss level, major Eurobot and FLL contests, as well as, for Robocup, the participation to the international committee. It has also helped in the organization of robotic competitions for primary and secondary levels in local schools (e.g. Fig. 1 and the video [15]), and various demonstrations. Membership [14, 18] and cooperation [19] have been extended to other contest organizations, in particular the FIRST Lego League (FLL), via Hands-on-Technology, based in Germany, and Robocup [19].

It is therefore natural that Robot-CH has been approached by academic institutions in the context of pedagogical experiments and curriculum revisions, as presented in the sequel of this paper. Experts of technical science fields of could join force with teachers and professionals of teachers education at academic level. A first step was made with the introduction of a novel course, oriented towards robotics and electronics, for a Master of advanced studies at the Pedagogical University of Lausanne (HEP-Lausanne). The second step focused on the introduction of robotics

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during the education of the teacher. Different robots (Bee-bot, Wedo and Thymio II) are used to teach the first elements of a simplified programming. The goal of this course is to introduce robotics to younger pupils and also to transform the wrong representation of robots associated to the masculine gender only. During these courses, many skills (communication, creativity, strategy of learning, collaboration) are associated with the setting-up of learning situations, in order to develop more science-oriented, logical minds and reflection attitudes.

4 MAS-HEP Course for Robotics and Electronics

In an attempt to improve education in STEM and MINT disciplines, at HEP-Lausanne, the concept matured to offer a novel course, oriented towards robotics and electronics, in the context of crafts (e.g. woodworking and metal processing) and handiwork (re. textiles) activities, at graduate level. This was experimental and, in case of success, would take a more permanent character.

Among key objectives of this 72 hour course (plus personal work), the idea was to open to many, the fields of electronics and robotics, yet considered by most people as out of reach; to bring basics for possible later extension within focused continuing education initiatives; to allow teachers to meet professionals in engineering; concretely, the assembly of a small electronic circuit, and the programming of an elementary robot was seen as an exercise to be replicated, under guidance, by future pupils. Equal parts were given for theory and for practice.

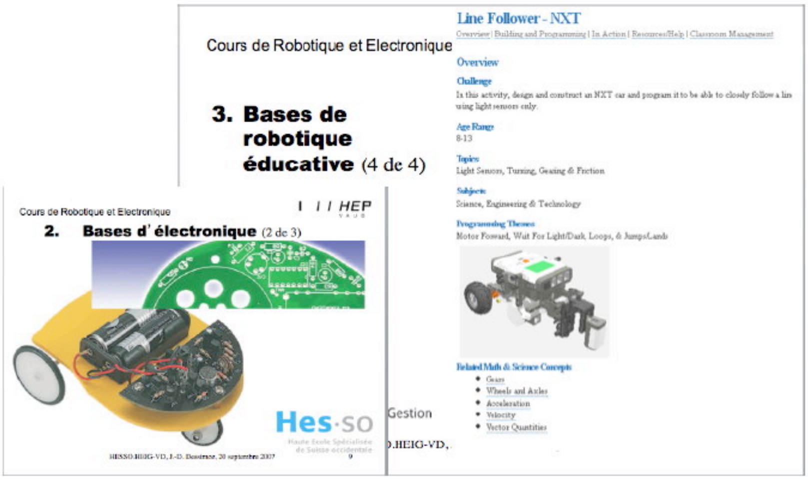

Fig. 2. Illustration of the first two thirds of the MAS Course 330-5 [20] : electronic circuit to assembly, for a system reactive to light or sound *(left)* and example of robotic task to program and implement *(right)*

The course consisted in three parts, the first one ensuring the assembly of a small, mobile, reactive system; the second one, the programming of a Lego-typed robot (Mindstorms), with NXT processor (re. Fig. 2), for an exercise comparable to what is done in FLL competitions; and the third one, essentially consisting in visiting private companies and research groups in electronics and robotics.

The rational of our choices for various, complementary robotic platforms included three critical parameters, in addition to essential pedagogical requirements : First, 1. simplicity and cost ; 2. availability on the market, with excellence of overall system concept ; and later on, 3. the proximity to dynamic local producers and experts.

Particularly positive results appeared in terms of interest from the participants; reports already useful as working documents for later teaching in classrooms (e.g. Fig. 3, [21-22]) ; and new contacts established between selected pupils and professionals in private companies, with the help of teachers who had benefited from this course.

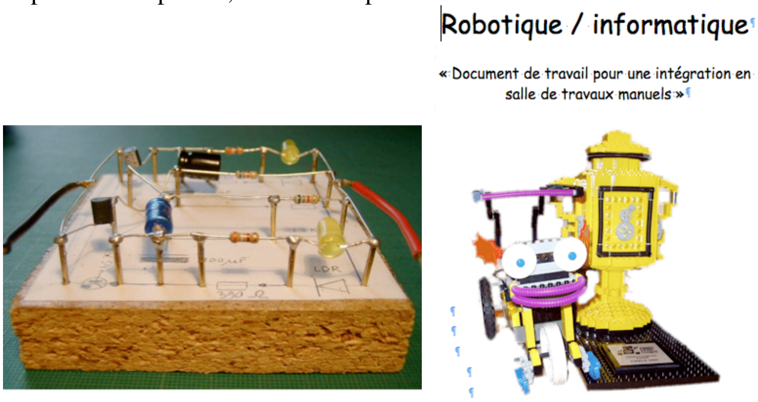

Fig. 3. Elements of reports made by MAS participants, contributing to concrete documents for subsequent teachers in classrooms: examples for electronics, Zahler [21] *(left)* and of robotic task to program and implement, Sahli and Demcik [22] *(right)*

The experience gained in this MAS Course could lead the way for a larger initiative, at Western Switzerland level, implemented in a five-year plan, as presented below.

5 "Piracef" Program

The experience gained in above described MAS course has led to a broader initiative, on a "perennial" basis.

Currently, a five-year program is under way at Western Switzerland level, where several academic institutions cooperate for a common curriculum, relating to crafts and home economics (PIRACEF).

Under the responsibility of Pedagogical Universities (HEP), a Diploma of Advanced Studies (DAS) is proposed, and novel courses extend classical craft and handwork courses, to activities in electronics ("AC 240") and, optionally, robotics ("electronics 2", "AC-277"). In addition, a special Research Methodology Day is organized, on a yearly basis (re. Fig. 4 and [23]).

A difficulty appears in terms of cost if robotic devices are widely used; currently, simpler electronic circuits, including analog and digital elements have been designed and are mostly used.

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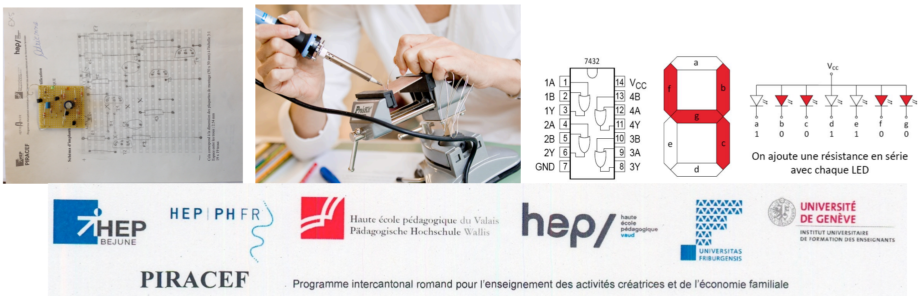

Fig. 4. As a test for knowledge acquisition, primary and secondary school teachers prove their understanding and ability to realize a simple electronic circuit *(above);* this novel initiative is coordinated at Western Switzerland level by 6 academic institutions *(below)*.

The courses and workshop laboratories take place at HEIG-VD / HES-SO, in cooperation with specialists for electronics and robotics. This turns out to be an interesting additional benefit of the program, as after this training the teachers know whom they can rely on for possible later technical support, and very importantly, they are also in a better position to inform the youth of the lifestyle and opportunities that technical sciences may bring them. As expected, some effective knowledge can be acquired by teachers and students in the basics of electronics, and robotics allow them to better understand current technological issues.

6 Conclusion

The good development of modern societies requires a substantial fraction of the population, and in particular of workforces, to be somehow expert in scientific and technical areas.

The paper has reported on a case in Western Switzerland where innovative and promising actions have been progressively set into place, in particular relying on robotics, for fostering novel changes in curricula for primary and secondary education.

This case study also shows that many “bottom-up” contributions are required for success: while, in particular, volunteers of Robot-CH, pioneers in pedagogical and engineering universities, and some enthusiastic teachers have already locally set into place a convincing novel training system for the benefit of youth, the Swiss federal government is just reaching the point to open a call for new projects in MINT context.

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