What can we hope of a technology education, which breaks off design to espouse science, mathematics and engineering?

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Abstract

From various forms of art and craft education, technology education has been based traditionally on the articulation between design, technology and use. It aimed to improve understanding of the existence's mode of the technical objects, through the social organizations by and for whom these objects exist. Based on concepts and references borrowed from sciences and the social sciences, this education privileges an approach by problem solving. It gives a broad place to the creativity and activities of group work.

Beyond these intentions, such structures are not simple to implement, at least in the French school's tradition. In fact, this teaching was organized according to logics of guidance and control opposed to these ambitions. In addition, under the pressure of the disaffection of the pupils for the scientific studies, many are those who think that it is necessary to reinforce the links between sciences and technologies in order to increase the social purposes of sciences. In this perspective, technology appears as applied sciences, or as applications of sciences.

To build a social meaning between sciences, technology, engineering and mathematics, the privileged link would be the process through which the mathematical modelling founds the production of the scientific knowledge, which organizes the process of engineering and induces the technological choices. This rationality excludes the design from the process and thus the links with the social sciences and the development of the creativity. For which benefit? We tackle this question in this presentation.

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Introduction

Linking science, technology, engineering and mathematic in education is a very recent approach of the school. This link questions the contemporary curricula organisations, the purposes assigned to these school subjects and the relevance of the knowledge to teach in each field thus built. Today, it is commonplace to say that academic disciplines are social elaboration that does not give directly and simply an account of the fields they are supposed to represent and they are supposed to refer. These recent evolutions are really and fundamentally different of the situation in the early eighties, when we introduced in France Technology education (TE). This introduction was different at the primary school, the lower secondary school and the upper secondary school. At the primary school level and at the lower secondary school, TE comes from an old tradition of handicraft education. The main idea is a progressive elaboration through the educational activities, to observe, to manipulate, to experiment, to make, to manufacture, to design. Pupils experience by themselves the structuration of the different subject from a sensitive and intuitive perception of the environment to rational relationships through knowledge (Ginestié, 2011b). At the lower secondary school, education takes the form of distinct subjects and "*technology*" takes a specific place distinguished of *"sciences"* or "*biology and geology*". At the upper secondary school, TE becomes optional with a great emphasis of industrial sciences and mechanical approaches.

At the same time, French system knew a strong generalisation of the access to upper secondary and higher education. This generalisation focuses on the aims of the school with a bipolarisation between general education and professional integration, in the context of disaffection and depreciation of the pupils for sciences, specifically at the university level. Giving more importance to education induces to rebuild the links between different fields of knowledge and their social role. This transition from school subjects, based on academic references (more or less legitimate), to educations to, based on social references closest familiar environments of students is not easy in it. It causes a break with a long established school tradition, rather badly by the teachers who live it as a challenge to their professional skills. The stakes are high and we will in this presentation, discuss some of the terms.

Knowledge, object and subjects...

The organization of general educations aims the goals of understanding through the methods, the knowledge and the point of view of the particular field of the school subject. Understanding an environment carries with the implicit need to establish relationships with the things comprising it. A thing becomes an object when a person (subject) establishes a relationship with it (object): S –> R –> O. The nature of the relationship defines the nature of the object. This relationship primarily involves constructing a meaning that will influence the subject's actions. From this point of view, learning bases on the process that involves forming relationships that will allow the subject to act upon and with objects built in this way.

Evidently, the same thing generates different objects according the kind of relationships established. This construction is individual and each person forms its own relationships. Each pupil will thus build in each teaching his own relation with each thing which he will have to study. However, objects are social constructions that fit into social meanings or contexts that are pre-established and shared within a given culture. From this perspective, school is the place of institutionalisation of a wide range of objects in which pupils will construct meaning about these objects and about people's relationships to these objects generally shared by society. Hence, a link exists in this process between, from one hand, the pupil's individual actions who build his own knowledge and, from another hand, the social "togetherness", which bears the knowledge giving meaningful to the objects shared by the community. From this point of view, the school subjects appear as fields of significances of the objects give to study by the teacher to the pupils. For example, the definition of the school disciplines, like mathematics, sciences, biology, technology…, delimits some collections of objects, more or less complex, and some families of relationships, more or less sophisticated. In fact, if one changes the global aim of education, one changes the delimitations of the collections of objects and, in consequence, the families of relations.

Understanding the world through the production of Technical Objects

As we said it, the introduction of TE in France aims various goals: understand the contemporary world, understand the mode of existence of the technical objects, and understand the social organization of work. Let us examine the technical attribute that one normally accords to a class of objects (Andreucci, 2006, 2008; Andreucci & Ginestié, 2002). An object is technical since it brings a technique with it, a manner of doing something in order to achieve a goal (Séris, 1994).

More simply, a technique can be defined as a traditionally effective act (Haudricourt, 1988; Mauss, 1936, 1948); we can also underline the fact that there is no technique without transmission (thus without tradition) not more than there is no technique without real (describable) effect (Sigault, 1988, 1994). The technical nature of the object means that one is presumably going to view it as something manmade and used in the good way, without ambiguity, by the subject (Simondon, 1989, 2005). This definition of the technical nature can be described as being external since it integrates the material nature of the object, the fact that it results from a human intention of manufacture and that it explicitly carries the goal for which it was designed.

As we can see it in TE, this understanding initially relates to the understanding of the mode of existence of the technical objects as well in their social existence as in their existence at school. As in many countries, TE was based on, in France, the articulation between design, technology and use of technical objects. This articulation is significant of the modern evolution of the relationships between the designer, the maker and the user, in the context of industrial production. Different points of view are possible to consider it; in France, we can summarize this through three. The first supports the entry by the human organisms of the production of these objects, and, in particular, the industrial production studied within the framework of the mechanical engineering. In this perspective, school activities must be relevant to the professional activities and they aim to understand the opportunities of professional careers; this pedagogy refers to social practices (Lebeaume & Martinand, 1998; Martinand, 1989, 1995). The second point of view is the entry by the methods of organisation of industrial production of objects. In this way, school activities are relevant of the different methods, skills and tools used at each stage of the process that goes through from the initial idea to the end of life of the object (Crindal, 2001; Ginestié, 2002; Rak, 2001); pedagogy is based on the method of industrial project (IPM). The third one gives higher rank to the human interactions through the articulation of the design, the making and the use of technical objects. This way focused activities on problems' solving and researches of resources (Deforge, 1993; Ginestié, 2005, 2008). More or less, TE, such as implemented in France, is a blend from these three points of view; that gives an approach specific and original but at the same time that weakens considerably this teaching, which has difficulty finding its legitimacy.

The introduction of innovation, as a motor of development, strengths the necessity to develop the creativity as way to produce different solutions for the same things (Atkinson, 2000; Barlex, 2007; Chevalier, Fouquereau, & Vanderdonckt, 2009; Kimbell, 2000; Lindfors, 2010). This approach may be considered from a longitudinal viewpoint and from a horizontal viewpoint. The competition between different companies, who produce the same range of products, imposes the differentiation of the products. The designer is in charge of this. He designs a new product, enough different of the others, specifically to allow the identification of the company but, at the same time, enough similar to identify it in the same range and family of objects. To grow, companies must develop new objects, which differ from previous generation, must mark the most explicitly the novelty included, in accordance with the tradition of the company. In the both cases, horizontal and longitudinal, creativity is the main motor of innovation and the designer is the professional in charge of the process of evolution and distinction of this new product.

Many times, we can observe many tries to introduce innovation and creativity as one major determinant of this process (Chevalier, Anceaux, & Tijus, 2009; Christiaans & Venselaar, 2005; Dorst & Cross, 2001). One noticed many nice experiments and pedagogical organisations to promote creativity, as motor of innovation and we are many to investigate the way to open school situations to the creativity's development for pupils. In France, for instance, there is a wide development of investigations around this link between design and manufacturing. Based on ergonomic approaches (Bonnardel, 2009), we try to understand how the creativity is taking account by designers and how we can introduce it in education. This conceptualisation gives us the opportunity to understand some key concepts of the teaching-learning process at school.

Creativity in the school situations is not so easy to be qualified (Rutland & Barlex, 2008). The production of several different solutions can be considered as an excellent indicator of creativity. The difficulty lies in the characterisation of these differences. It shows that the multitude of solutions is not a sufficient criterion of creativity and it is not sufficient to ask students to produce a multitude of solutions. This description of the differentiation of solutions produced imposes to find some criteria of the diversity and the originality. The educational management of this creativity through the diversification of solutions produced by students has a direct impact on possible pedagogical organisations (Barlex, 2007). At the lower secondary school, these difficulties have an impact on the pedagogical dynamic and one observes a phasing out of situations that might develop creativity. It costs much more, in terms of teachers' commitment, to develop activities in which students can experience their own logic relating to design, manufacturing and use (Ginestié, 2011a). Teachers use the models more and more formal from engineering of industrial production. In doing so, they focus on the part of manipulation of tools and methods – and therefore the time spent to the learning of these operations – at the expense of the construction of social meanings of these manipulations.

A more global understanding of the world

From the social point of view, innovation and creativity are main motors of development of the modern companies, one most significant symbol of high-tech industries (Lindfors, 2010). TE has to deal with this concept by which the innovation and the creativity would be one of the engines of economic development, opening the occasions to keep a high level of social development. Recent economic and social evolutions, the emergence of new economies like China, India, Brazil..., fossil limits of the exploitation of resources and ecological balances..., equilibration of the North-South development..., all these reasons and beyond, show the limits of a model of growth based on the consumption and, in fact, the limits of a TE based on this logic. The technological project-based method is not enough significant to give the understanding keys of our contemporary world. It needs to be more situated on the global understanding of the interactions between the human activities and the world balances (Kimbell, 2000).

Our recent evolution minimizes the place of academic knowledge to the benefit of "educations to". To play a role and have a fulfilled citizenship in our contemporary environment focuses more attention on general skills and understandings to elaborate, to analyse and to interpret the facts (Zeidler, Sadler, Simmons, & Howes, 2005). School is no longer just the place where children learn the basics to read, write and count. It is no longer, at least in its part of education for all, the place of familiarization to specialized knowledge in a particular academic field. It is not, either, the only exclusive place, outside the family circle, of transmission and construction of institutionalized knowledge in which the teacher is simultaneously the referent, the guarantor and the transmitter. Inseparable from the three skills (to read, write and count), the ability to reason is fundamental for children to reach this rank of the reasonable, thoughtful and social adult who takes its place in society (Middleton, 2005). Probably, the articulation of design and technology as school subject has not developed (or insufficiently) the capacities to reason (Leplat, Veloso, & Aamodt, 1997). Many researches have shown that the implementation of this teaching has largely relied on the modelling in school of some methods borrowed from industry. At least in France, this focalisation on this kind of structuration left a small space to the student's initiative for problem solving or solutions finding. This trend increased with the development of the use of computers and CAD softwares.

This set of concurrent facts leads at focusing on engineering methods at the expense of elaboration process of several different solutions. Gradually, one abandoned the idea that the design of an object, which can bring the human dimension of its use, and based on the determination of the use functions and the esteem functions, was an essential phase of the TE. There is in the process to articulate science, technology, engineering and mathematics, simultaneously the will of a global approach but an approach based on the rationality of mathematical, scientific, technological or procedural modelling (Ellis, 2007). That is at the expense of rationality for developing any solutions in a design process that relies on the integration of constraints, their possible prioritization, the choice of the best solution, the most relevant, the most economical or the most environmentally friendly... In this sense, there is a risk through the generalisation of the STEM approach to lose this construction of meanings by reinforcing the acquisition of formalized procedures in the technical languages to the detriment of the development of semiotic thought.

This is particularly important because, many researches have showed that, the construction of knowledge that allow to act on his environment - and understanding is one of the first level of action - involves this dual structure of procedural and semantic cognitive schemes. This is one of the major contributions of research on teaching-learning processes, analysed through activity of the pupil, the teacher and the interactions between the two. In terms of "education to", STEM represents a significant development by the opening up of academic disciplines. This orientation strengthens the relationships for the students between the different fields of knowledge by expanding the scope of their understanding. However, the structures of teaching, the choice of the situations and teaching methods that will be implemented are crucial. It is another conception of the teacher's profession, who will have difficulties for positioning themselves against the academic traditions. That means that we have to develop some training plans for these teachers, and beyond, to accompany this major evolution. Without doubt, this is the point, in France, we will probably give us the most difficulty due to the deterioration of teacher training organisations.

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