RELATION BETWEEN TECHNOLOGY EDUCATION AND SCIENCE EDUCATION: 
A DIFFICULT ALLIANCE

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Summary
The French school system is marked by the difficult alliance by the past between science and technique. The coexistence of manual work and objects lessons already was difficult. With the birth of middle school at the beginning of 1960, there are numerous tensions about contents (physics phenomena or technical process) and about pedagogical approach (investigation or realization). The conflict has been stopped (about 1975) when technology education has been clearly distinguished between experimental technology (or applied sciences) within science education in order to initiate engineers for the future and more vocational technology (or general technology) whom the aim was to prepare technicians careers (entrepreneurship, project process, practical knowledge). This curricular organization with two different school subjects was legitimated by their different functions. The coexistence has been implemented to the beginning of 2000 and has been jointed with the vertical organization of each school subjects: from nursery school to tertiary school (engineers schools and technology within university).

1. Introduction

Within general education, “Science and Technology” is an usual label that identifies an educational area with its purposes. Currently, this question is important and is a political issue. The European Commission aims to organise the basic education with an associated or integrated set or a pillar of science and technological culture with mathematics, experimental sciences (biology, geology, physics, chemistry) and technology. It’s an international movement, for example in Quebec (Barma, 2007; Hasni & Lebeaume, 2008). But, the recent proposals of Rocard report (European Commission, 2007) with the only approach defined by Inquiry Based Science Education doesn’t take account of the specific epistemology of Technology, which is analysed by de Vries (2005). Layton (1990) indicates the three main possibilities of existence of Technology connected with science: such as applied sciences, experimental approach of devices or in science-technology-society prospect.

The current context and the purposes of knowledge society focalise on the new qualified employments and a new citizenship. The needs of technology education and its school functions are deeply changing. Within general education, technology education with its epistemological singularity and its differences has to be again defined in its social and educational functions.

In order to examine this major issue, a first part proposes an analysis of curricular system in France and its structure historically content driven and where technology education needs to be different of science education. After this historical point of view about contents, the paper focuses on the main confusions concerning the relationships between these school matters.
mainly about the experimental approach in its epistemological and pedagogical aspects. The third part develops a frame to investigate new contents and organisation of technology education within compulsory school and mainly within middle school.

2. Technology education such as a school matter: tools for analyse

In France such as the most other countries technology education is a school time specifically identified after primary school (teachers, classrooms, timetables…) and it’s different with its development within high school (contents, teachers) (Deforge, 1993; Gradwell & Welch, 2003; Mottier & de Vries, 2006; Wright, Washer, Watkins & Scott, 2008). This situation is jointed with the history of school system and the integration of technical education within it.

2.1. Technology education: coherence

In order to analyse technology education, a model is proposed (Lebeaume, 2000, 2004). It questions the foundations of the contents about the prototypical situation of each form. This teaching-learning is characterized by the tasks, their significance, and their orientation: What exactly are the pupils doing? And why are they doing it? How do these tasks refer to outside practices? Figure 1 illustrates this coherence in the reciprocal relationships between the three components of this discipline: purposes, references, and tasks.

![Diagram of Coherence](image)

Figure 1: Coherence

By the past, there are numerous differences between manual work. The main distinction has been about the references about scientific knowledge and technical practices. The two pictures (Figure 2) illustrate this opposition between references and the difference of tasks.
This internal analysis has to be completed by an external point of view in order to indicate the functions of the school matters within the educational policy. Technology education is different if it serves to personal development, careers information or producing of workers.

2.2. Technology education: distinctions

From the analysis of main types of curriculum proposed by Ross (2000), Lebeaume (2008) distinguishes the repartition of contents and the main forms of technology education according to knowledge, competencies or experiences.

On the figure 3, one plan is opposed to one axis. It enables to distinguish 1) the teaching-learning considered about the process or the products; 2) the role of pupils: knowing or acting; 3) the contents-centred pedagogical methods, the competencies-centred new original situations or socialization-centred. The contents are different in reason of the main priority to say or to do, to understand or to succeed, to learn or to appropriate or to incorporate values and empowerment.
Technology education does not exist spontaneously in the French school system. It’s a long history included in the dynamic of designing and implementation of compulsory school and of the organization of others scientific school matters. There has been numerous tensions about its specific contents and its relationships with scientific school matters especially physics-chemistry.

In order to understand the French situation, it is necessary to analyse the proposals from the second war when the compulsory school still was to 14 years. The analysis is driven across a set of documents which are political discourses and pedagogical proposals about contents (Charlot & Figeat, 1985; Lebeaume, 2008). It underlines the context and the socio-economic stakes, the trends of educational policy, the main pedagogical orientations, the contents and the labels of school matters. With this analysis with these different levels from policy to pedagogy, we can define five main periods (matrix 1). These briefly described five periods focus on the innovations.

3.1. Five main periods

Arts and crafts and home economics : 1942-1962

The beginning and the middle of 1940th is marked on one hand by the first project of unified school system and on the other hand by the development of technical education and its teachers’ education. The main element is the accent on pedagogical active methods for the boys and girls judged with a concrete spirit. In order to prepare workers, the principles are not only to prepare gestures and how to do but to explain the principles of actions and the reasons of technical choices. It’s usual to define technical contents in their relationships with applied sciences. In the same time, there are several innovations for young pupils in order to define their aptitudes for the best choice of careers: the arts and crafts are implemented for their educational virtues. For the young girls, it’s the development of home economics in order to prepare women at their two careers. This education is deeply valorised by technical schools and more modestly by primary schools but very criticised by secondary schools that prefer to only teach knowledge. The arts and crafts and home economics define an experiences-centred education. It’s implemented by women and female teachers with the new certification for this education (1950).

Technology : 1962-1975

From 1959 the compulsory school is prescribed until 16 years. The main issue of the educational policy is to define the new middle school and to prepare at school pupils for the choice of careers, especially to the new upper level after high school. At this date, the policy makers have to create this new education different of a vocational education (Deforge, 1970). It’s not very easy without specialized teachers, without administrative and pedagogical organisation, without equipment… They define three “Technology Education”: an experimental or scientific technology useful for good pupils who like concrete approach, analysis of devices and graphical expression. The second technology, more vocational and adapted for less good pupils who have to choice a manual or technical career at the end of compulsory school, valorises technical realizations in workshops. The third technology is a familial or home technology useful for the whole of pupils, boys and girls, in order to prepare them to the use of new devices or products of the modernity. The institutional and material conditions only enable to design and test the first technology with two main aspects: an
active, concrete and experimental approach; contents centred on functional analysis in order to understand the technical thinking.

![Figure 4: Three Technology Education](image)

But the launching is more difficult in reason of the simultaneous implementation of science education, especially in physics and chemistry. This last school matter exists within high school and within primary school in the objects lessons. Numerous engaged officials criticize this gap and they claim physics within middle school with the same status of biology and geology. Middle school then is a ground of conflict between technicians and physicians but with unequal terms (Harlé, 2003). The programs of physics and technology develop the analysis of devices. The ones focus on phenomena studies, the others on functional analysis. This proximity is the base of confusion between the two school matters, the ones judging the prior of sciences on techniques. Technology is only considered such as applied sciences or such as a pedagogical means for science education.

**The distinction between science and technical education: 1975-1985**

When the middle school is generalised for the whole of young people, the school law limits the conflict with the implementation of the two school matters: physics and chemistry; Manual and technical education. In reason of economical and political circumstances scientific technology education is a part of science education (physics) and technical and manual education develops vocational technology (handwork) and home technology (home economics, usual devices). This choice focuses on the differences between pupils with the choice of their career. But this division of contents really is not implemented and experimental technology doesn’t exist: physics only develops a scientific approach in order to discover and learn universal law, experimental method and contents knowledge. There also is an alliance between biology-geology and physics-chemistry in the area that is labelled experimental sciences. These school matters constitute a set with an equal position: a vertical coherence from kindergarten to university, contents knowledge in relationships with mathematics, contents useful for the pupils selection. Technical and Manual Education has not the same function and status. Mainly for poor pupils and their life preparation, its concrete approach and its focusing on practical experiences, their teachers without a pre-service education at university… are a few of its characteristics.

From 1980, “Technical and Manual education” is contested by the specialists of technology because they hope to develop best qualifications of technicians. The contestation takes on school contents and on school activities because they are judged too referenced to workshop and not to industrial process and methods.
In 1985, technology is a new school matter in place of Technical and Manual Education. It’s a period of its vertical implementation from kindergarten to university and engineers' schools. For middle school, this time also is the certification of technology teachers. The curricular structure is with experimental sciences and technology. There are three different school matters with their independence, their own functions and their distinct contents. Such by past, technology focuses on school orientation and vocational orientation while the priority of biology-geology and physics-chemistry is the development of scientists. Technology valorises technical project process while sciences focus on knowledge. These differences are located on the figure 5.

![Figure 5: Technology and Experimental Sciences](image)

Technology is a school matter of realisation and experimental sciences are a school matter of knowledge. The difference also is about the pupils who are producing pupils or knowing pupils. The main choice for technology is to answer at the diversity of pupils and their possibility of school pursuit at high school within vocational education or technological education.

In order to understand, we have to look at the technological education and its need of development limited by the decrease of pupils. With the vertical organisation of school matters, technology education is not isolated of its high version and the engineers education.

**Engineering sciences and Experimental sciences: 2000 –**

With the government change, the development of "hands on" approach of science education within primary school (la main à la pâte), the new discourses about the need of scientists and engineers, the issue of number of students in this area at university… the tension between industrial and tertiary general inspectors, and the proposal of a new curriculum with a basic education, the idea of the integration of scientific school matters is proposed. Simultaneously, technology education and its orientations with project process, its little realisations in electronics, mechanics and economics are very criticized by the minister and policy makers. Technology education then is illegitimate because there are new special courses especially concerning information technology and information about careers.

Without particular functions, technology education integrated among scientific school matters and with the pressure of one technology teachers association and the industrial technology inspector, becomes a school matter of knowledge. The contemporary official discourses
prescribe this fundamental change and define technology education such as a little version of "engineering education" (Ministry of national education, 2008)

The five moments are summarised in matrix 1.

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<td>Need of new technological competencies</td>
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<td>School Policy</td>
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<td>Arts and crafts and home economics</td>
<td>Arts and Crafts and Home Economics Home Technology</td>
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Matrix 1: Curricular organisation of science and technology education in France

3.2. Forty years of technology education in France

The history indicates the conditions of its existence in the curriculum. Technology such as a school matter is legitimate when its purposes answer to educational policy, i.e. when its function within school system is agreed with economical and school stakes. Then the co-existence with science education is possible because their functions and their contents are different. Within a subjects-centred curriculum there is a necessary difference between each school subjects about their function, their contents or their methodological orientations (Goodson, 1992).

But currently, the context is not this one. In order to exist technology education has to have the characters of this set of school matters with the main key words: investigation approach, experimental method, knowledge and competencies… This location is difficult in reason of numerous confusions.

4. Main confusions

4.1. Epistemological confusions
One of the confusions is about the experimental methods in technology education. The general opposition is about science process and technique process, their purposes and their characters. Most of researchers indicate the difference between discovering the world and building it, to understand the past and to design the future, to define universal law and to specify particular artefacts, to study phenomena and to use them or to control them... This question is a false issue because the experimental spirit is included in the technical rationality. But the technical rationality is not reduced to experimental process (Lewis, 2006; Roth, 2001; Van Eijck and Claxton, 2009).

On the other hand, the nature of the hypothesis is a fundamental difference. Within science an hypothesis is a proposal built in a theoretical framework which is discussed with the findings of several experiences which bring the validity. In the realm of techniques, an hypothesis don’t focus on this validity but on the confrontation of a project and its feasibility, on the choice of different solution in a complex set of constraints, on the list of potential solutions within the domain of possibility. It’s the characters of the practical science (praxis).

Technology education is a scientific school matter, not simply with the method of experimental science but with the foundations of practical sciences. In this sense, technology is not applied science but it is more than applied sciences (de Vries, 2005). But in France, there is the force of the ideological position of the scholars and engineers with their hierarchy and their status (Le Châtelier, 1947).

4.2. Pedagogical confusions

The confusions also are in the pedagogical discourses. The investigation approach or the inquiry based science education (UE, 2007) serves two discourses: the one concerns epistemology point of view, the others concern the lessons or activities organisation. On the figure 6, we can locate these two discourses which can simultaneously exist. It is the difference between what pupils do and what they learn. Figure 6 presents the necessary passage from the one to other in the “secondarisation” process of teaching-learning (Bautier & Goigoux, 2004).

![Figure 6: Investigation: epistemological and pedagogical aspects.](image-url)
The same confusion is about problem solving. Middelton (2003) has shown its specificity within technical and scientific areas. It’s possible to discuss its function for teachers and pupils in its pedagogical role or epistemological nature.

5. An example to think and to discuss the relationships between science and technology

5.1. For a theoretical framework

Black and Harrison (1985) proposed by the past a schema in order to locate science and technology. Their proposal is organised across “Task-Action-Capability”. Lebeaume (2006) suggests the questioning of each school matter in their relationships concerning their integration or their coordination (figure 7)

![Figure 7: Coordination between school matters](image)

5.2. An example

The example is the Radio Frequency Identification technology (RFID) with its numerous uses in transports, safety, automatic and robotics and in daily life such as individual identification with labels under the skin. These current uses are not put in questions and are considered as a magic technology. Only a few newspapers discuss the need of public rules about this means of traceability that enables to follow each person with the risks of surveillance of the private life. In spite of the social stakes and societal stakes of this technology, the school contents don’t take account of it. The claim of the social legitimate of this subject questions its eventual introduction in curriculum: what, how, when.

From the point of view of how it works, a label RFID is composed of one microprocessor with an antenna made by a brass thread. The reader activates the label by waves radio. The electromagnetic field generates by induction an electric current which feeds the chip and which then can communicate its data or modify them. Those essentially descriptive elements of this technology may then be a school contents of an education conceived as a monographic approach of the contemporary objects like the general sciences and the objects lessons of technology. However, such an education(teaching) limits itself to a presentation(display) which suggests only a reduced work of the thought with all the limits of this informative approach. Other approaches are conceivable as more experimental or inquiring activities which would allow to seize the conditions of functioning according to the variation of the
distance, the electromagnetic field and the components. Other activities are also possible from the conception of models that enable pupils to enlighten the constraints for the industrial and tertiary implementation of such devices with several labels. In another perspective, it is also possible to centre the pupils' activities on the stakes of discussion and of debates of the involvements of this technology which they use but which they do not know. These activities may enlighten the citizen or force the thought to underline the principle of functioning, to build a functional model and to discover it according to several points of view. The interactions between technological contents and included scientific contents are opened at once on the approach of the phenomenon of induction and the phenomenon of transfer of information in a comprehensive prospect.

The major question still is "when" because this subject of study RFID can be at once a detached activity or a serial activity according to the distinction of Delon (1887) about the progress of the objects lessons. In other words, this question is the one of the registration of this subject and the activities in a continuum and thus the guiding thread on which they join: it is then about a dominance centred on the functional analysis which would privilege the comparison of technical solutions to the problem of the identification or a dominance centred on the electromagnetic spectre or still the information technology.

The curricular decisions on these programmatic choices depend fundamentally on envisaged aims and on references. They can thus to give place to educations very contrasted with privileged ambitions: critical education of the aware citizen about societal repercussions of this technology, discovery of the solutions of a technical problem, an appropriation of objects and systems of the daily life, an exploration of the scientific phenomena and their applications. Naturally, a composition of set is also possible but however with the risks of tensions born with the hegemonic positions of some and others.

The main obstacle to the appropriation of the contemporary technical environment is the incommensurability of the technologies and of the networks of information and communication that are the most evident and the least perceptible. How to approach and to conceive this imperceptible and immaterial environment? What are the indispensable intellectual elaborations to seize them in their complexity? The notion of information seems in this respect inescapable associated with the notions of detectors and of devices which allow then to translate the technical functions and the transformations of the physical dimensions they operate.

The privileged point of view is then the functional analysis that enables at once the study of the technical solutions, their comparison and even the determination of new solutions adapted to defined constraints.

The educational and psychological stakes could then be the progressive construction of this model of the technical systems with the prospect of liberation of the spirit. This model represents these intellectual tools of the thought. This proposition, at the level of the contents, may become integrated into a set that would privilege a more experimental approach, more practical, more citizenship, more inventive, more scientific and technological, in an integrated education or divided education.

6. Discussion
This presentation shows the difficult alliance between technology and physics in reason of the competition between them and the difference of status in its three aspects, school, social and scientific (Léon, 1980). The main question is to define and to discuss the set of questions:

- What are the purposes of technology education and science education, in their cultural stakes, school stakes and cognitive stakes within general education? According to answers, technology education may be more near of:
  - Engineering education with knowledge in mathematics, physics, chemistry or biology eventually associated or integrated in a project approach; it is a combined solution in order to develop the experimental thinking and the technical thinking.
  - Applied sciences with the priority of science education and their applications in different areas;
  - Information about science technology society with a best knowledge of the sociological context of science and technology development, their epistemology;
  - Vocational education with high relationships between school and labour or enterprises;
  - Practical education in the rational use of technologies;
  - Entrepreneurship education with the development of specific competencies in order to implement projects, to organize collective activities, to communicate in a team…

In the foundations of education, is it an integral education (heart, hand and spirit) or a school matter whom the purposes are to train the spirit only in a cognitive perspective. This choice is a political choice for the recognition of technology education within compulsory school.

What have pupils to do during the school time?

It's a pedagogical question about the choice of approach. The main opposition is between investigation approach and realisation approach. But in the two cases the same points are present:
  - Scientific or technological investigation : to underline phenomena or specific characteristics of technical solutions in order to understand scientific principles or technological principles;
  - Scientific or technological realisation with the difference between model and artefact, object and product. The main difference is about taking account of constraints

- What are the external references of the school activities?

The history indicates that technology education references are either academic subjects or social and technical practices. Which game do pupils play at school? What are their roles, engineers and technicians or scholars and scientists?

- What is the beginning and the temporal organisation of science, technology or engineering education? Is it more coherent? This choice mainly depends on the teachers’ education such as engineers or scientists.

  - to begin by physics and mathematics before to develop technology ;
  - to mix this school subject ;
  - to don’t distinguish school matters and to develop a global approach.
The main question is about contents in general education. The choice of contents depends on the precedent questions but it is important to take account of the current development of technology in order to understand, to design, to criticize, to use, to participate and to live in the contemporary technical realm.

Note
This contribution is sustained by National Research Agency (ANR): « Réformer les disciplines scolaires : acteurs, contenus, enjeux, dynamiques (années 1950-1980) » REDISCOL,

References:


