Integration of Science, Technology, Engineering and Mathematics: Is this Curricular Revolution really possible in France?

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Abstract
The French school system is a subjects-centred curriculum from the beginning of 1960s. This deep-rooted organisation tends to block the several attempts made to integrate the teaching of scientific school subjects. From an historical point of view, this paper describes the curricular system and the issue of its current change.
It focuses on the main issue about separation or integration of these subjects in secondary school.

Key words
curriculum studies, didactics, history, school-subjects

1. Introduction

In the worldwide movement for science education change (Giordan, 2010), the orientation of integrated science teaching appeared in France from the second half of the1990s. Science-Technology-Engineering-Mathematics (STEM) did not designate integrated science because of the different curricular organisation in primary school and first and second levels of secondary school. In primary school and first class of middle school, the educational policy tended to develop an Integrated Science and Technology Teaching (ISTT) implemented by one teacher only. Nevertheless the new law of education (2005) defined Mathematics, Science and Technological Culture as one of the seven pillars in the basic education for pupils until age 16. In the first level of secondary school, there was a cross-curricular approach of three school subjects – Sciences of Life and Earth (Biology-Geology), Physics & Chemistry and Technology – taught by three different teachers. In the second level of secondary school, age 15 to 18, there were several attempts to develop common teaching with Experimental Sciences, Mathematics and Engineering Sciences subjects. The first analysis revealed difficulties in this new approach (Harlé & Lanéelle, in press; Coquidé, Lebeaume & Robert, 2008) and the General Inspection's report suggested to continue the (ISTT) test according to local teams' decisions only (Perrot; Pietryk & Rojat, 2009).

This paper explains the French context and submits an analysis of these unfruitful innovations. It argues that the deep-rooted organisation within a subjects-centred curriculum implies many obstacles. It also discusses the curriculum change and its conditions, mainly the necessity to take into account the historical process through which school subjects are defined and established in their epistemological and social dimensions.

2. Subjects-centred curriculum: Features and issues

The curriculum studies revealed their differences according to their organisation with their ideological, political and social foundations (Bernstein, 1975; Musgrove, 1968; Young, 1971). These sociological analyses revealed the fundamental distinction between a subjects-centred curriculum – or subject-based; knowledge-based; academic – and a pupils-centred curriculum. The first one emphasised on the teaching of separate subjects and the second one favoured the pedagogical approach by themes and learning of integrated subjects. Bernstein (1975) described these two broad categories as collection types in which units or divisions of knowledge were strongly bounded and had a hierarchical organisation and transmission mechanism. The integrated type allowed for interdependence between units of knowledge in a less rigid thematic approach, with less dependence on the relative positions of teachers and pupils (see Ross, 2000). Forquin (2008) summarised the main features of subjects-centred curriculum as the autonomy or independence of each subject with their valorisation of disinterested knowledge and the disqualification of contextualised or utilitarian knowledge, with their competition and their selective ambition, their route to universities and their retention strategies.

This opposition was also the philosophic distinction underlined by Dewey (1962). But Goodson (1994) claimed that this choice was not only in relation to the philosophical principles or social and economic structures but was also influenced by teachers, social groups or lobbies who had an interest in promoting their views about school subjects or curriculum. He noted that: "subjects are not monolithic entities but shifting amalgamations of subgroups and traditions which through contestation and compromise influence the direction of change" (Goodson, 1994, p. 42).

At this perspective curriculum history enlightens the foundations of choice, debates and conflicts. As in Great Britain the school system in France was developed from the Second World War to the end of 20th century and moved from a three separate schooling type to a common type. But the British comprehensive school and the French *Collège unique* (1975) had re-established the old tripartite system. Differentiation was defined by school subjects. Goodson (1992) differentiated academic subjects from technical and manual subjects. Ross (2000) describes

these three main types of school subjects three types of curriculum. From a synthesis of historical analysis in Great Britain, he described the content-driven curricula that essentially developed academic knowledge towards universities, the objectives-driven curricula that aimed at utilitarian and vocational competencies leading to the process-driven curricula that promoted socialisation, attitudes and volition. Ross proposed a hypothetical matrix organised around these three different definitions of curriculum linked to three different axes. In order to analyse French reform, Lebeaume (2009) suggested that the curricular organisation distinguished different subjects that specifically promoted knowledge, competencies or experiences in relation to schooling pursuits, employment needs, social order and pupils' aptitudes (Figure 1). But in France this type of schooling organisation dominates discussion about the political choice between primary school order and secondary school order, i.e. between academic schooling or utilitarian or experiential schooling and with no room for debate on technical school order.

The history of technology education (Mottier & de Vries, 2006) indicated its long conquest for existing in the secondary curriculum. In the French school system Lebeaume (2003) identified the different stages with the contents transformation of successive matters labelled as Manual Work (1945), Educational Handicrafts (1953), Technology (1962), Technology-Physics (1970), Manual and Technical Education (1975) and Technology (1985). He noted instability between arts, handwork, applied sciences, engineering sciences…. But these moves may only be understood in the subjects system with the parallel move of other scientific school subjects in order to be established. Instead Goodson (2005) explained there was a continuous pressure from subjects with less esteem, which began stressing their pedagogic and utilitarian traditions for an academic tradition.

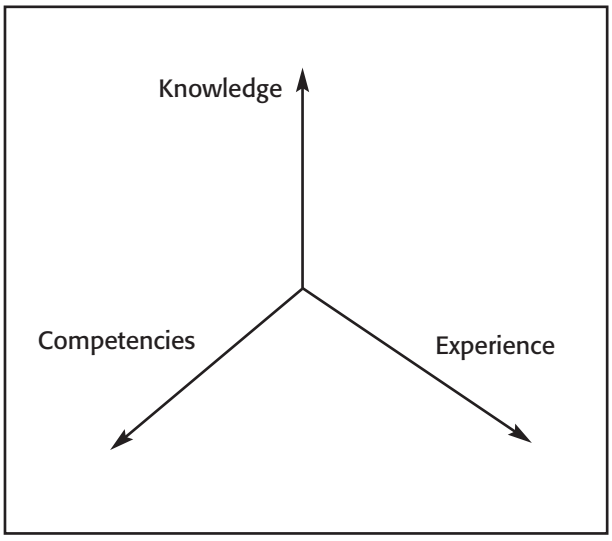

Figure 1. Three types of school subjects

However we argue that the current change to integrate scientific school subjects was particularly sensible because of their different status and the need to undo the disciplinary system in which the engineering sciences had not been yet established. In this perspective a historical survey focused on the simultaneous development of science and technology education was submitted.

3. A historical survey

The historical survey focused mainly on what was considered as internal factors and actors for the construction of science and technology education. Nevertheless this internalist perspective suggested by Pannabecker (1995) needed to be linked with the political and economic context and with the main laws concerning employment and vocational training during the long period of scientific and technological development.

With this orientation, the source material referred to official texts, curriculum documents as well as relevant handbooks, textbooks and professional articles. Hallström (2010) indicated that these documents were seen as authoritative texts and had a decisive impact on the content of a subject. The source material concerned the different school matters that existed from the end of the Second World War: home economics, manual work, technical education, natural sciences, applied sciences and mathematics. The analysis was chronological and it identified the changes within the curriculum. It concerned secondary school only.

The results were divided into five main periods from 1945 to 2008.

4. From school matters to subjects-centred curriculum

At the end of the Second World War schooling was compulsory until age 14. The period of reconstruction began in France and employment increased. During the same period the education report "Le plan Langevin-Wallon" was submitted. The project dealt with the school future and stressed for a more democratic and common school. Unlike other countries, education reform was only agreed in 1959 and compulsory schooling reached age 16. But the birth of the middle school retained a tripartite organisation with three main types of education: classical, modern and practical.

4.1. Pending reform: 1945-1959

In 1945 the school differentiation was still organised according to social background. Secondary school was

accessible for the upper class only. In France students could either continue their schooling in special grade or begin their technical education in a new school type – les centres d'apprentissage – to become qualified workers. Then mathematics was taught in all grades. Science education was organised around the traditional objects lessons model type with an extension to applied sciences to city or countryside daily life. The contents varied for boys and girls for whom home economics subject had been compulsory for ages 14 to 17 since 1942. The curriculum included also manual work with a practical orientation.

During this period two main points were discussed. The first point concerned the teaching of science. The orientation of the science of common things was contested because it was considered too remote from the subject with its own experimental reasoning. The second was related to manual work. Indeed the secondary school and technical education representatives believed these activities were very useful to identify students'abilities. This design initiated by technical education inspectors to fit into secondary school changed this school matter as "handicrafts education" (1953).

4.2. The middle school and its tripartite organisation: 1959-1975

From 1959 to 1975 the reform was implemented. Science education tried to conquer its place in this era of modernity. It was the phase of vertical construction of science education as a school subject especially in modern school. Until then indeed the natural sciences were taught from primary to high school classes but this was not the case for physics and chemistry subjects. This gap was pointed out by scientists who claimed the economic need in recruiting researchers and engineers and therefore the necessity for a continuous education from lower grades to high school.

But there was a strong conflict with this teaching in modern school. Was it in relation to science education or technological education? Was it an experimental approach of scientific laws or a concrete approach of technology knowledge? In 1962 indeed the new "Technology" subject was tested in the last two grades of middle school. The contents focused on the functional analysis and industrial drawing through the analysis of mechanisms or devices. Then Technology was defined in opposition to manual work or vocational education to help guide students towards higher technological studies being established in secondary school (sections of upper technicians: 1964) and in university (Universitary Institute of Technology: 1966). But Technology was still not established in middle school: no equipment, no specialised teachers and no academic discipline. The pressure of scientists was much stronger than the pressure of engineers and in 1970 a hybrid school subject – Technology-Physics – was taught in all classes.

At this time the students' schedules shared educational handicrafts, technology-physics, natural sciences and mathematics. But it was also the period of the contents reforms. In 1967 The Lichnérowitch committee worked on the modern mathematics reform. Mathematics became a major subject while sciences were considered as a minor discipline. The French Society of Physics, the French Society of Chemistry and the Physicians Union became a dominant group. The major challenge was then the science education position and its equivalence with mathematics education. In 1971 the ministry created a committee to update physical sciences and technology teaching methods. The analysis of the committee's work indicated the imbalance between science and technology education (Charles, Lebeaume & Lamoure, 2008; Harlé, 2003). Their proposals included creating an integrated science and technology teaching through several topics such as electronics, automation, industrial production, polymers and plastics…. These proposals were tested in classes with teachers especially trained.

4.3. The first phase of common school: 1975-1985

By 1971 the Vocational Training Act amended technical education. Indeed technological and vocational educations were differentiated. Technological schooling was identified in the educational system for the first time.

With the new President in France (1973), the Minister for Education submitted a new plan (Haby, 1975). The project introduced two new courses: experimental science education and manual and technical education for the middle school organised as a common school (le collège unique). At the same time educational handicrafts and home economics were taken out. This curricular reorganisation did not take into account the Lagarrigue committee's proposals of an integrated teaching of sciences and technics.

The purposes of the two new subjects were different. Experimental science education – biology-geology and physics-chemistry – aimed at researchers' training like technicians and engineers while the manual and technical education prepared students to vocational education and low-skilled jobs. The difference was amplified by the distinction between teachers, first to be university-trained unlike primary teachers, handicrafts or home economics teachers or teachers with a technical education. There was

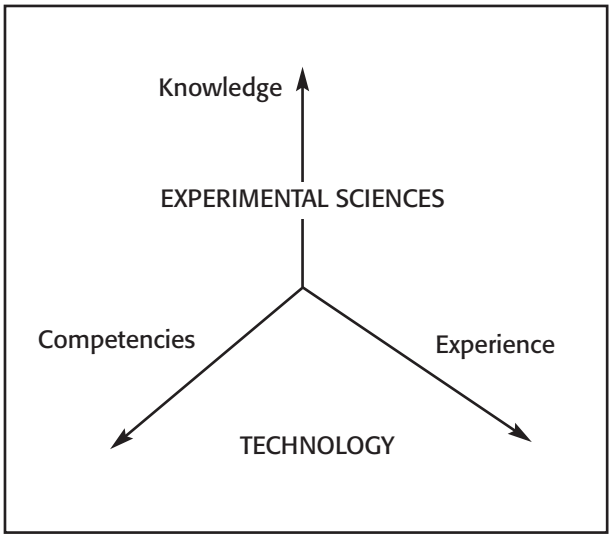

Figure 2. Technology and Experimental Sciences

thus a great status distinction between these school subjects: the first one had features of an academic subject unlike the second one. This distribution is shown in Figure 2. It froze the curricular configuration at the time when vocational education was at the lowest level in the educational system. Martinand (1996) argued that the prospect of an integrated science and technology education was definitely impossible.

4.4. The second phase of common school: 1985-1995
Once the organisation was established, school subjects were strongly separated. With their specialised teachers, Mathematics, Experimental Sciences – distinguishing Biology-Geology from Physics-Chemistry – hence Manual and Technical Education became separate and were defined as four school subjects. The second phase of common school reinforced that separation with the teachers' specialisation and their certification as teachers of secondary schooling.

The only main change was the transformation of manual and technical education into a new subject "Technology Education". This change began at the end of 1980s when the economic crisis implied technological development. It was implemented in the new political circumstances linked to the arrival of the leftlist government (1981). "Technology Education" then began its vertical establishment from middle school to high school. Contents were new with the development of computers, robotics and tertiary employment. Technology knowledge was progressively defined towards project process, value analysis and economic principles in marketing, language of automation, electronics or mechanics phenomena, new modeling tools… But there was still a distinction between middle school and high school. It was a transition time for middle school: manual and technical education teachers were trained to the new subject whose pedagogical and administrative organisation was shared by two General Inspections: industrial sciences and technics, economics and management. The manual and technical education with its General Inspection disappeared. Therefore a new qualification for teachers was created in 1988. Technology teachers had the same status as mathematics, physics-chemistry and biology-geology teachers.

This period established the school subjects-centred curriculum. This rigid partitioning required minor adjustments with cross-curricular themes like security, health or consumers education. But these topics without real instructors were not really taught. However the Technology education process of becoming a real school subject was not yet finalised.

4.5. Towards the end of common school: 1995-2008
The end of 20th century was marked by a political change and several reports on middle school were submitted. The endemic failure of school questioned its efficiency. The first project on the design of basic education for all pupils was discussed. The National Council of Syllabus proposed a new curricular organisation around a few clusters one of which was scientific and included mathematics, sciences and technology. The school subjects-centred curriculum was shaken.

There were some curriculum adjustments. In high school technology changed its label to Engineering Sciences. This affirmation of technology knowledge did not affect middle school where the new programmes (1996) were confirming the project approach. But it was a period where numerous confusions arose from the word "Technology". Among the policy makers, nobody knew really the meaning. Technology was often used in the sense of educational technologies, information technology, applied sciences or vocational education. This school subject was weakly supported by the new inspectors whose main concern was implementing Engineering Sciences in high school. Physics-Chemistry was also an issue in middle school first classes. But this adjustment broke up its vertical structure and implied many challenges when the students' lack of interest in the scientific branch became an international issue. It motivated a renovation plan for science and technology subjects in primary school. It was the generalisation of the operation "la main à la pâte" initiated by the Nobel Prize in Physics Charpark and supported by the Academy of Science (1996). A hands-on approach was his pedagogical principle. But the proposals and resources showed a greater priority to

physics than biology and did not resolve the confusion existing between technology and applied sciences.

During the debates about the basic education, the balance of power was largely in favour of science education. The new technology education programmes written by a team of experts chaired by a physics-chemistry Inspector General focused on the design of applied sciences. This orientation enabled to imagine a similar pedagogical approach: the investigation method with hypothesis, experimental protocol…this pedagogical approach was generalised for each school subject in this pillar of common core (2008): mathematics, physics-chemistry, biology-geology and technology. Seven interdisciplinary topics as such as statistics, sustainable development, meteorology, health education…were also defined.

During recent years, a new Inspector General has been in charge of Technology education. He completed the vertical structure of technology on the one hand in initiating the engineering sciences in the early grades of middle school and on the other hand in suppressing tertiary technologies content. From that moment on Technology was a subject of knowledge.

5. A long history: The weight of the past for an uncertain future

This history has showed the long process of establishing a subject centred curriculum. It revealed the gradual distribution and positioning of each discipline. It has thrown light on alliances and conflicts; the strongest one being between Technology or Engineering Sciences and Physics-Chemistry. This history may be used to explain the current difficulties or reluctance in changing the curriculum and thus breaking its compartmentalised structure.

In the same way the justification of an integrated science and technology education in the early grades of middle school (2007-2009) was not generalised. This extension of "la main à la pâte" – supported by Science and Technologies Academies – in secondary school raised many concerns and suspicions against the risk of loss of identity in an undisciplinary set. Furthermore in Rocard's report (European Commission, 2007) the recent European proposals with their only approach defined by Inquiry-Based Science Education was weakly accepted because they did not focus on the specific contents of each course and school subject. In a similar way recent attempts to amend the teachers' certification allowing them to teach two scientific subjects were challenged by professional unions.

When it takes more than half of a century to stabilise a curricular structure, change requires probably the same amount of time because it is based more on social than strict epistemological organisation; and particularly here where change is seen as a break with tradition and a revolution.

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