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Twenty years of evolution in French secondary school science textbooks

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Abstract

Textbooks are highly structured objects, which are easily distinguished from other types of publications such as popular science books or academic works. This recognisable shape results from section-specific formatting, and layout standardisation. Yet these structures change over time and differ according to school disciplines.

Our aim is to understand textbooks (specific resources) in themselves and grasp their evolution dynamics. Our approach here is to examine textbooks in both descriptive and analytical ways, using a comparative approach, and focusing on science high school textbooks, over a period of 20 years. The main questions steering our analysis are: What are the basic components of these textbooks? How to identify elements that are common to various school subjects or stable

over time? What trends seem to be emerging? We have sought to highlight – via an analysis of school programme changes – some shared features that shed light on the directions that these school subjects and their supporting resources seem to take.

Keywords: science, textbooks, France, resources, programmes

1. Introduction

In France, the State defines programmes but is not involved in textbook production, which is left to private publishers (Bruillard 2005). Publishers rely on authoring teams, mainly composed of active and specialised teachers, in this case, science teachers. Textbooks are therefore products resulting from constraints imposed by different logics (Radtka 2013): the economical logic, which includes the constraints of meeting the unspoken and not necessarily convergent expectations of the different audiences to which the textbooks are dedicated (teachers, parents and pupils) (Chopin 2005); the technical logic of book production, DTP softwares and printing systems; and the disciplinary logic, not only driven by the prescribed curriculum (injunctions, texts and official speeches), but also depending on the produced curriculum (educational practices, resources used). Textbooks designed within this framework are part of the potential curriculum (Martinand 2003). Products at the crossing of all these logics, textbooks are, both markers but also drivers of these complex systems that are school subjects (Bruillard 2005).

Textbooks in French science didactic research are considered as indicators of school practices and representations of teachers. Analyses, essentially qualitative, focus on knowledge content aiming towards epistemological criticisms, didactic transposition analyses (Savaton 2005) or identification of learners' obstacles (Magneron 2005). Our approach is of a different type. Our aim is to apprehend textbooks (specific resources) for themselves and grasp their evolution dynamics. We seek to characterise their referential (relation to prescribed content), documental (document positions and roles) and instrumental (teacher and pupil support tool) functions (Chopin 2005).

Textbooks are highly structured objects, which are easy to distinguish (almost intuitively) when flipping through them, from other types of publications such as popular science books or academic works (Lucas 2006). This recognisable shape results from section-specific formatting and layout standardisation. Formatting is

also a major constraint in the textbook design process, binding ideas and their displays (Radtka, 2013). Yet these structures change over time and differ according to school disciplines.

Our approach here is to examine textbooks in both descriptive and analytical ways, using a comparative approach, and focusing on science high school textbooks, over a period of 20 years. The main questions steering our analysis are: What are the basic components of these textbooks? How to identify elements common to various school subjects or stable over time? What trends seem to be emerging? Which are the fluctuating items?

Once we have characterized some of the textbook changes, we have sought to highlight – via an analysis of school programme changes – some shared features that shed light on the directions that these school subjects and their supporting resources seem to take.

1.1. Approaches and methods

We have focused on two, so-called experimental, school science subjects: 'Physique Chimie' (PC) (physics-chemistry) and 'Sciences de la Vie et de la Terre', (SVT) (life & earth sciences). They are taught, in parallel, from the first year of lower secondary level (Collège) to 'Seconde' level, which is the first year of upper secondary school (Lycée). Both share a special feature in the way they cover two scientific disciplines: physics & chemistry for PC and biology & geology for SVT. If for years now, SVT easily combines the two disciplines thanks to its focus on subjects (such as soil for example), which encompass biological and geological aspects, it is not the same for PC. PC only became a combined discipline in 2010, through unifying themes such as sports and health. All textbooks studied herein are of 'Seconde' level. First level of general and technical upper secondary education, 'Seconde' is a determination level, common to all secondary education students since 1981. At the end of the 'Seconde' year, students must choose between different streams of studies (scientific, literary or economics).

The twenty-year period, from 1990 to 2010, spanning three educational reforms and curricula changes (1992/1999/2010) has been retained for our analysis. This period seems relevant for understanding what textbooks are today. It will enable us to get a good picture of what they have been; that is to say, of what they are not anymore, and of what they still are (in terms of layout, structure and knowledge contents). Except for rare occasions, we have limited ourselves to 1993 and 2010 textbooks, whereas publishers offer new editions approximately

every 4 years. Without trying to be comprehensive, we have studied a sufficient number of textbooks to identify specific components, and similarities and to reach saturation of our analysis parameters. The following presents results from 12 textbooks issued by leading textbook publishers: three for each period and each school subject.

Our analysis methods are driven by an internal vision of textbooks. Our analysis criteria are not imported from another discipline. A "custom grammar" (systematic study of elements and rules of a language) is designed, based on the first observations made on the entire corpus. Thus, our syntax elements are the basic building blocks of textbooks. Our comparative analysis is based on systematic investigation of the entire corpus, looking for these building blocks. The analysis uses quantitative and qualitative methods, structural criteria, specific items (images, natural and technical objects) and content analysis for some components – mainly activities – and from pedagogical and taught-objects perspectives. Organisational criteria at various scales concern overall book structure, chapters' internal structures and also specific sections (lessons, activities, practical work).

This approach allows us to reveal the existence of strong invariant components and of strong and homogeneous structures within the studied textbooks. The presentation of our research and the identification of the basic components is combined here with the analysis of their evolution over time. This allows us to characterise the components according to their status: invariant or specific to a period or to a school subject.

2. Textbooks under scrutiny

2.1. Textbooks growing thin

Textbook volume has been decreasing over the past 20 years, in several ways, and for both school subjects. First, in 1996, all publishers offer a single volume, combining physics and chemistry parts. This also applies to SVT where biological and geological parts have been combined for a long time. In 2010, several publishers offer, in addition to the standard A4 format, a more compact edition closer to an A5 format, like many news magazines, as well as digital versions.

The number of pages, disparate in 1996, converges in 2010 and generally decreases. While the average number of pages in PC (282) remains higher than

in SVT (269), the gap narrows down in 2010, going from a 27 percent to a 20 percent difference. Furthermore, the variation between numbers of pages in textbooks on the same subject tends to decline in both PC and SVT, with a very strong trend in the former, as in 2010, this variation is inferior to two percent.

2.2. Moving book structures

Analyses of the various global structures reveal strikingly similar structures between textbooks, independently of period and school subjects. The different basic components identified in our analysis are presented in Table 1 (below). It displays in a synthetic view their presence or absence in textbooks allowing to identify trends. Only components identified in at least three textbooks, in one column, are shown in this table.

Zones	**Headings**	**PC 1990s**	**PC 2010s**	**SVT 1990s**	**SVT 2010s**
Presentation	Introduction	***	*	***	**
	Table of contents	***	***	***	***
	User manual	**	**	*	***
	School programme	**	***	**	**
Main body	Topic introduction	*	***	***	***
	Lower school education refresher	*	*	***	***
	Chapter	See Table 2			
Appendices	Technical sheets	***	***	***	***
	Corrected exercises	***	***	*	***
	Lexicon			*	***
	Index	***	***	***	**
Cover	Flaps	***	***		*

Table 1: Overall structure

An asterisk represents the occurrence of one particular heading in a studied textbook.

A textbook is made up of three distinct zones. The first gives an overview of book content and its organisation (the pages "school programmes" are located either at the beginning or at the end). The second zone corresponds to the main body – a sequence of chapters – and contains most of the pages. The last includes various appendices. The flaps (between two to six pages) on the back (or added) to the cover are not counted in the total page numbers.

SVT textbooks changed little between the 1990s and 2010s, while a significant change occurred in the overall structure of PC textbooks. Until 2010, PC textbooks displayed two separate parts; one for physics and the other for chemistry, each divided into sections. One textbook only (Nathan 1997) opted for a theme parting; themes being themselves split into chapters – three Physics topics followed by three Chemistry topics. In 2010, all textbooks have a similar three-parts structure; each part corresponds to a programme theme. They are becoming more like SVT textbooks, which, in 2010, shifted from four to three themes. But, as early as 1993, SVT themes were intertwined, without any graphic distinction. Biological and geological topics can be included in the same chapter, such as soil surveys. Whilst in PC, chemistry and physics chapters are juxtaposed sometimes even alternately without any link (some textbooks label chapter's subject-type) .

In 2010, all PC textbooks display official programme's instructions and the number of pages devoted to those is increasing. Two out of three textbooks present the entire programme and a list of corresponding chapters. Information on guidance and occupations are spreading but do not always have the same format, ranging from a half-page insert at the very end of the chapter to a series of double pages at the end of the topic. Collège's refresher headings are not found in all textbooks, even in small inserts. New pages – in *Logos* (Nathan 2010) and *Competences* (Hachette 2010 – have also appeared.

In SVT, a user manual is systematically included which explains the structure in a visual manner. Corrected exercises are relocated at the very end of the textbook – as usual in PC – while they were scattered at the end of each chapter in 1993. A lexicon or 'dico SVT' appears in all textbooks. Expanding components tend to occupy a whole page, and even sometimes, one or more double pages, whilst initially these appear either scattered or in small inserts. Generally, these expanding components are outside of the main body resulting into an even smaller allocation of space to core contents (scientific knowledge contents) in 2010.

2.3. Copycat chapters?

The analysis of the structure of the chapters shows, likewise, that PC chapter organisation has changed and surprisingly converges toward the structure in place in SVT textbooks since the 1990s (see Table 2).

Headings	**PC 1990s**			**PC 2010s**			**SVT 1990s**			**SVT 2010s**		
Number of chapters	30	24	26	**20-**	20	17	13	6	20	**16**	15	13
Introduction pages	1	1	1	**1**	2	1	2	4	1	**2**	1	2
Activities pages	1.6	2	1.6	3	3.5	4.2	9.9	20	8	**6**	6.5	8.3
Lessons pages	4.7	5	4.3	**2,4**	2.9	4	2	2	3	**0**	0	0
Summary pages	1	1	½	**1**	1	1	2	1	1	**2**	2	2
Exercises pages	3.7	3.2	3.5	**5,8**	4.1	6.3	4	1	3	**4**	3	4
Corrected exercises pages	1	1/2	1	**1**	1	1	1	0	0	**1**	**½**	0
Going further pages	0	0	0	**0**	1	0	0	0	0	**2**	2	2

Table 2: Chapter structure

Each number corresponds to the number of pages in each textbook for the related heading (except for the first one).

2.4. Double pages style

In SVT and since 1993, headings of chapters (introduction, activities, knowledge summary) have been traditionally presented on double pages. The activity pages in particular, contain three to four insets including various documents (photos with captions, experimental setups, experiments results). In 1996 PC, the double page is rare, aside from being used to delineate the textbook structure: in Belin and Hachette, an illustrated double page marks introductions of "Physics" and "Chemistry" parts while Nathan uses a double page to introduce themes (six double pages instead of two). In 2010, the number of double pages has

increased; as all PC textbooks use these to mark a change of topic (Nathan even adds one at every change of chapter). These also appear within the chapters. For instance, Hachette has designed two new double-page layouts: One – located after every lesson – includes a summary face-to-face with multiple choice questions and some detailed corrected exercises (exercice résolu); and another one at the end of each topic, which describes occupations and propose synthesis exercises.

From 2010, a “going further” section called "scientific and civic culture" appears on a double page in all SVT textbooks as well as Nathan’s PC. Various inserts relating to occupations, careers (jobs descriptions, interviews of professionals) or interdisciplinary issues with other sciences and even art are displayed including also generally history of science issues.

2.5. Activities first!

In SVT textbooks, the order of headings is almost always the same. In particular, activities are always offered at the beginning of the chapter, before the knowledge summary. By contrast in 1996 PC, the lesson (description of physical principles and models, laws and methods) is upfront. A practical worksheet (TP: travaux pratiques) (one page, rarely two) is located after the summary of the lesson. Less systematically, it is followed by a set of questions. Nathan 96 innovates by renaming practical work "experimental activity" and inserting it within the lesson for some chapters. In 2000, the Helios collection by Hachette reverses the order between the activities and the lesson. But only by 2004, is this order overwhelmingly adopted by all publishers.

Other significant changes include a reduction in the number of activities per chapter in SVT, while these increase in PC textbooks.

In 1993 SVT, just after the activities, a double page provides a condensed lesson, usually followed by a one-page summary, in the form of a short text and diagrams. The condensed lesson disappears in 2010. Therefore, the only remaining content concerning knowledge is a summary on a double page, always combining diagrams and short texts. In PC, lessons are still present in 2010 but the number of pages slightly decreases, and is sometimes even reduced to a summary (as in three chapters in 2010 Hachette). This trend is expanding in Hachette 2014. The summary, limited to a small insert in Nathan 1996, takes an entire page in 2010, as in all PC textbooks. Similarly, all textbooks offer a detailed corrected exercise spanning over a page with drafting or methods of reasoning aids.

With diminishing numbers of lessons pages, increasing activities pages and reversed order of sections, PC chapters are like those of SVT.

2.6. Navigation through colour codes

To help navigation, publishers chose to use graphic codes including colour labels to identify various parts and types of activities inside or outside chapters. These colour labels, already used in 1996, are more complex in 2010. For instance, in 1996, two different colours highlight physics and chemistry and colour banners identify specific data-sheets and exercise areas. In SVT, colour codes are used only by 1993 Hatier to differentiate lower secondary education refreshers as well as knowledge summaries from the rest of the chapter. In 2010, the combination of coloured titles and thumbnails (located in corners or on edges of pages) identify the type of activity and the topic to which the chapter belongs. There are more colours (up to six per page in addition to black and white, versus two or three in 1996). The six 2010 PC and SVT textbooks use these principles with very similar colour palettes which accentuate their likeness.

2.7. Even more colour thanks to images

In SVT, main body texts are always printed in simple and easy-to-read black fonts on white backgrounds, while documents and activity titles are also printed in black using the same font as in the text but enlarged. In the 2010s, all titles become much more colourful, with blue, red and green, and even white fonts when they are superimposed on a coloured area. These coloured insets are much more common in 2010. They break the monotony of the white background. They are used in two out of three SVT textbooks to indicate set of questions; text fonts are still always black.

In 1996 PC, main body text fonts are black and either on a white background or on a coloured background in specific contents boxes, another colour being used for titles. These two colours are fixed for a whole section (physics or chemistry). In 2010, each heading has its own defined colours while keeping some titles in the theme colour.

The trend of increasingly coloured textbooks is also due to the increasing presence of all kind of images; especially colour photographs in both science textbooks (see Table 3 below).

1990s	**PC 1996**			**SVT 1993**		
Textbooks	**Hachette**	**Nathan**	**Belin**	**Hatier**	**Nathan**	**Bordas**
Pages	400	336	368	287	239	320
Photos	325	278	340	282	139	229
Photos/Page	0.81	0.82	0.92	0.98	0.58	0.71
Total images	684	567	635	414	263	707
Images/page	1.70	1.68	1.72	1.44	1.10	2.20
2010s	**PC 2010**			**SVT 2010**		
Textbooks	**Hachette**	**Nathan**	**Belin**	**Hachette**	**Belin (2014)**	**Bordas**
Pages	336	344	336	256	287	264
Photos	468	480	312	234	334	275
Photo/Pages	1.39	1.39	0.92	0.92	1.16	1.04
Total images	679	644	515	416	601	655
Images/page	2.02	1.87	1.53	1.63	2.09	2.48

Table 3. Pages, pictures and images in physics and chemistry, and life and earth sciences textbooks over time.

Total numbers are indicated. Ratios represent the number of items per page.

Images are categorised according to photographs, diagrams and drawings in SVT; while, in PC, photographs, diagrams and graphs are distinguished. These different category choices are explained by the fact that there are virtually no drawings in PC but we wanted to distinguish between graphs representing mathematical functions, which are much rarer in SVT. Surprisingly, PC textbooks are very rich in photographs; photos per page ratios are almost always higher than in SVT textbooks. This sharp increase between 1993 and 2010 is mainly

due to an increase in the proportion of pictures in exercise sections (six times higher). It is the same trend for the images per page ratio in 1993. In 2010, SVT textbooks have the highest ratios on average but these ratios are also more spread, mainly because the number of diagrams varies widely between publishers. The average number of drawings appears to be slightly on the rise in 2010 but their nature has changed. On one hand, the practice of accompanying photographs, such as one of microscopic observations, with interpretative drawings decreases or disappears in 2010. On the other hand, traditional hand drawings also decrease and are mostly replaced by drawings made with graphic design software. In PC, the total number of images varies little between 1996 and 2010; this is explained by a decrease in diagrams in favour of photographs in 2010 (the number of graphs being almost stable).

2.8. Rigid PC layouts

The evolution of layouts is only partly convergent. In 1996, PC textbooks page setups are exactly the same: lesson text occupies two thirds of the page, and images (photo, table) generally one third on the right side. For exercises and practical worksheets, all textbooks present information in two columns. Within documentary activities, texts are formatted in three columns and images of varying sizes are sometimes spread on the entire width, as in newspapers. In SVT, at that time, page setup was less standardised; some containing areas where images occupied the entire width of the page, and short texts (especially in Bordas), others having a page setup similar to PC ones, such as in Hatier.

In 2010, PC textbooks soften layouts for activity sheets, resembling those of SVT. Text formatting is adapted to the varying size of images and documentary texts. For instance, in Nathan and Hachette 2010, activities are sometimes written in two columns of equal width or of 2/3:1/3 width; sometimes texts and images are spread across the width of the page, and even in some cases, layout varies within the page. By contrast, lesson and exercise layouts do not change at all.

2.9. All sorts of activities

Activities provided in textbooks have become more diversified over the 20 years but paradoxically tend to be similar in both school subjects as regards to the presentation and the requested tasks. All SVT 1993 textbooks include a number of activities by chapter, which are classified as ‘practical activities’ or ‘documentary activities’. Their mode of presentation is already very similar: documentary activities include a set of images with captions, text excerpts accompanied by a ‘guide d’exploitation’, meaning a list of detailed questions to guide analysis. In practical activities, experiments are presented in detail, along

with sufficient guidance to be achievable in the classroom (installation diagram, protocol, chemical concentrations, incubation times). Nevertheless, results are always given, allowing the pupil to answer questions even if the experiment has not been completed in class. Questions focus on simple computing tasks, results analysis, protocol and experimental set-up critiques, but also on formulations of hypotheses. In documentary activities, displayed experiments are often more complex in terms of equipment and experimental know-how, and would therefore not be feasible in the classroom.

In PC, the trend is to not give experimental results as experimentation and completion in class are expected. However from 1996, Hachette has designed practical worksheets in which all results are provided. These then become sources of information and explanations to pupils who can thus understand experiments without carrying these out; these are also ready-to-use resources for teachers. The sparse "experimental activities" sheets that Nathan inserts throughout lessons pages also give experimental results and are used to support the lesson. These sheets were removed from pupils' textbooks with the 2000 programme reform and transferred to teachers' textbooks. This gives evidence of the ambiguity of these multi-recipient books.

In 2010 in SVT, documentary activities take over practical activities. The nature of the latter also changes. Activities involving observations (microscopic, natural environments) significantly decrease in favour of experimental-type activities, focusing on solving practical problems. The scales at which living organisms and biological processes are studied diversify, moving to a more global vision at the scale of ecosystems or the planet. The increase of documentary activities goes alongside the development of multidisciplinary approaches, for instance, using documents such as geography maps.

Hence, the activities address issues around the involvement of SVT in human affairs and how SVT can provide an explanation of the world we live in.

In PC, activities have increased significantly overall: however if experimental-type activities still prevail in PC, the share allocated to documentary activities has increased, particularly in connection with the history of science. The questions are less detailed; the focus on techniques and handling of instruments decreases in favour of approaches, general principles, and understanding of phenomena. In this new format, the two types of activities (documentary and experimental) are barely distinct from each other except through a title or a logo, sometimes labelled as 'investigative approach' ('démarche d'investigation'). Various documents are

included: texts, , diagrams, photos; sometimes animations, and films. Website references are either internal (from the publisher website) or external. In Nathan and Hachette, structural differences are still marked. For instance, the protocol is always given in experimental-type activities while for the investigative approach, pupils must design the protocol by themselves based upon initial questions and specified equipment. The 2010 Belin offers less documentary activities, but the boundaries are increasingly blurred: some activities even combine experiments and Internet research. The list of equipment is always provided. Activity sheets sometimes provide experimental results and pupils are tasked to analyse documents which often refer to history of science. The protocols to be used in the investigative approach are to be found throughout textbook sections. Nathan offers many investigative activities; almost every chapter proposes activities, mostly of a documentary type, as homework for the pupil to prepare for the next lesson.

This ambiguity between practical and documentary activities has massively spread in SVT; indeed the use of titles such as ‘sequence’ or ‘units’ is now preferred to that of ‘activity sheets’ and there is no distinction anymore between different types of activities. Today, experiment protocols are there only to support understanding results and the ‘guide d’exploitation’ asks fewer questions, giving the pupil more autonomy. In this line, Belin 2014 presents a pedagogical approach called ‘tâche complexe’ (complex task) in which there are no intermediate questions guiding the analysis of documents but only one global question. The pupil is therefore required to independently conduct his own investigation, to structure his approach step by step and to build his argument. Possibly, as in PC, he may be requested to propose experiments and to design protocols.

2.10. Experimental activities in PC

In 1996 PC textbooks, practical activities are well named as they mainly focus on handling technical systems and instrumented measures. Questions focus on settings, safety guidelines and comparisons between instruments and measurement techniques. Analysis of measurement results allows verification of the formal laws of the lesson. If we take the example of refractive phenomena: in 1996, in the question ‘What simple relationship links the sine of the angles in the experiment?’, the law appears simply induced by the measures. In 2010, the device to use and the measurement protocol have not changed. But after the manipulation, the laws of refraction are provided for testing; the work not only consists in verifying the law given in the lesson but also in appreciating that measurement results are consistent with the law formulated by Snell and

Descartes (Hachette). In Nathan and Belin, one must compare measurement results with different laws proposed at various periods by scholars (Grosseteste, Kepler, Descartes and Snell); then one must validate or not their theory (Belin) or assess their areas of validity (Nathan). The latest Hachette edition (2014) adopts the same presentation. In this case the experiment is used as a step in the scientific approach.

2.11. History of science joins PC activities

History of science has already been well established in PC textbooks since 1992, but only appears in SVT textbooks in 2010. Little space is dedicated to history of science in all textbooks, usually in a chapter's introduction or conclusion; however its usage is fairly contrasted. It ranges from historical anecdotes – merely for illustrative purposes – to succinct presentations of the evolution of scientific concepts (featuring excerpts from primary sources) through documents prompting reflections on historical and science and technology studies (STS) themes (importance of models in research, women in science).

Since 1996, PC textbooks present documentary activities based on historical features; one about Mendeleev is based on photos, manuscripts, and a summary of the history of the construction of the periodic table of chemical elements (without primary sources). Another strategy used by all 1996 textbooks is to elaborate on names of scholars quoted in lessons (Avogadro constant, law of Lavoisier, Lewis representation). In this case, pictures of scientists are displayed with a short caption linking their achievements to concepts of lessons. In some textbooks, some of the presented historical topics are not mentioned in the official programme.

The space allocated to history of science in textbooks clearly increases in 2010. It is often integrated within ambitious activities and less often embedded in lessons. In Belin textbooks, history of science is often integrated into exercises. In the other two textbooks, historical activities are usually more documentary-like and related to the theme of the universe.

Usually, historical aspects are aimed at introducing activities, but we also find summaries of the evolution of ideas and descriptions of experiments. In each PC textbook, a different historical topic is used in a kind of historical investigative approach. Thus, the only common historical references are the ones already developed in the 1996 textbooks: Mendeleev – still explicitly cited by the 2010 programme – and Snell, as he is related to an important lesson concept, refraction.

2.12. Disappearance of (technical and natural) objects

In SVT, the lists of living organisms mentioned in 1993 textbooks are quite eclectic and diverse, even though the same classic model of organisms and widespread cultivated species are named in all of them. Thus, the tomato is the only species, along with waterweed, quoted by all textbooks out of about twenty species mentioned in photosynthesis and crops chapters. Hatier mostly presents crop species cultivated in Europe in addition to an original reference to trees. Nathan uses crop species grown in Africa (cassava, groundnuts); Bordas displays the largest variety of species by incorporating non-food crops (iris) and even wild species (water chestnut). In 2010, species diversity is highly reduced. For instance, Hachette remains focused on conventional crops: wheat and waterweed. In all 2010 textbooks, living parts are referred to as generic types such as organisms or cells, without any indication of the species' name and detailed information about it. This contrasts with the 1993 textbooks, where every named species is accompanied by a photo or commentary providing details about its culture or its uses. There is also much less anatomical detail of organs and cell types. Only Belin 2014 specifies cellular localisation of photosynthesis, using cells of waterweed and naming organelles (chloroplasts) in which it takes place. Other 2010 SVT textbooks propose experiments using either leaves or whole plants without ever indicating the specific site of photosynthesis.

In PC, we observe the same type of reduction in terms of technical objects. In 1996 textbooks, studies on natural objects (vocal cords, ears) are linked with those on complex objects from daily life (microphone, camera, television). Several chapters include manipulations and measurements. Numerous technical sheets are devoted to measuring instruments (oscilloscope, multimeter) that pupils have to master. The technical systems (ultrasound, sonar, X-ray, optical fiber) used in various sectors are either mentioned in lessons or detailed in fact sheets. In chemistry, industrial methods (synthetic fertilisers, distillation, cracking, reforming oils) are illustrated with pictures of industrial plants. Numerous photographs depict materials (pieces of copper, iron, aluminium, liquid petroleum, plastic materials). The sections dedicated to atoms and molecules are illustrated by 3D compact models. In physics in 1992, technical objects have a major place in documentary sheets, including technological innovations (video game joystick, telescope, electric scooter, carbon fibres) and items not mentioned in the official programme.

Most of the objects or systems studied in 2010 textbooks are already present in 1990s textbooks. However, they are both fewer and less studied as specific items. The multimeter has disappeared and a fact sheet is still devoted to the

oscilloscope in Nathan and Belin but not in Hachette. The objects present in all three textbooks are typical optical objects: the prism and the half-plexiglass cylinder – a simplified version of the Silberman apparatus – to study the laws of refraction. As they support the study of physical principles on which medical applications are based, optic fibre, medical ultrasound or x-rays, are the only technical systems quoted in official programmes. Photos of industrial plants have almost disappeared and are replaced by pictures of flowers or medicinal products. The presence of pharmaceuticals, bottles, tubes and pills has increased generally, not only under health or sport topics.

2.13. How much IT in SVT?

In textbooks, the presence of computers (use and representation), either of a general type (like the Internet, digital work area (Espace numérique de travail (ENT)), office software) or more specialised (computer-aided experimentation (ExAO), specific software) has increased in the past 20 years, especially in SVT. In 1992, mainly ExAO activities appeared in textbooks – for instance, gas release measurements during photosynthesis – as computers became more and more common. Some textbooks show many pictures of experimental setups where central processing units (CPUs) and computer screens are depicted along with screenshots of measurements. In 2010, while ExAO is commonplace, computers are not represented anymore even in the scarce experimental setup graphic representations, as if its role was so obvious that it does not need to be specified. Many software programs are mentioned; Bordas and Hachette generally contained screenshots of DNA sequence analyses, of 3D-molecule visualisation, phylogenetic analysis but explained little about software manipulation. Regarding microscopic observations and their representations, the evolution is very clear. In all three textbooks in 1992, focus is on representation of observation in technical sheets, particularly on pen and paper observational drawings. Hatier SVT, a pioneer in 1993, devotes a technical sheet to image processing (digitised via a scanner). In 2010, only one textbook still devotes a technical sheet to manual observational drawing; the other two only focus on numerical representation and observation techniques such as 3D- molecular visualisation.

In PC, in 1996, except for a few screenshots, computers are not represented. In 2010, they become visible especially in doubles page introduction photos. The use of software increases slightly. In 1996, two software programs: harmonic analyzer in physics and CAD-molecules representation in chemistry are presented. In 2010, among the three specific software programs – sky simulator, video pointer and 3D molecule representation – only the video pointer is used in

all textbooks. Nathan and Hachette detail user instructions for the video pointer and also for spreadsheets in technical sheets.

The so-called general technologies, including the Internet, appear in 2010 in both school subjects through website references in the introductory sequences or as a tool to find additional information for activities or in specific documentary research exercises leading to the writing of scientific arguments. Some SVT textbooks include a technical sheet explaining how to find online resources. In addition, all paper textbooks refer to their digital versions available online, offering pupils free access to specific contents and to subscribe to others and, offering for teachers and institutions to buy the version for the whole class

2.14. What about programmes?

Text styles and their level of specification have evolved over time. Prescribed content and activities as well as their organisation provide different views of school subjects over different generations.

Shorter and simpler texts

The length of programme texts sharply shortened and their organisation was simplified. They are about three times longer in 1992 (28 pages PC, 20 SVT) than in 2010 (10 pages PC, 13 SVT). In 2010 PC, a preamble contains eight paragraphs and gives an overall presentation of the objectives for the ‘Seconde’ level (first year of upper high school, lycée). In SVT, the programme text is organised around three main parts, with a preamble of five paragraphs addressed to the entire upper secondary education level. A ‘Seconde’-specific preamble of two paragraphs outlines the major features of the contents, specifying their degree of generality. Comments that were thought to be of significant importance in 1992 and 1999 have completely disappeared in 2010 for both subjects. There are now only a few lines to introduce each topic.

The 1992 PC programmes contain some guiding principles applicable to the entire secondary school, specific objectives for ‘Seconde’ level and finally, for each main part – physics and chemistry – an introduction and a table with two columns: ‘contents’ and ‘minimum competencies’. Each content section is followed by a list of activities given purely as a guide. In 1992 SVT, the table contains three columns: ‘content’, ‘cognitive objectives’ and ‘potential activities’. In 1999, the ‘potential activities’ column disappears in PC. In 2010, only a few examples of activities remain scattered in the columns ‘competencies’ in PC or ‘abilities & attitudes’ in SVT.

2.15. PC topics

In 2010 PC programme is written as if all contents belonged to the same subject. It is divided into only three topics: health, sport and universe. In 1992, two separate sections 'physics' and 'chemistry' are presented, each divided into three topics. Among these (tension and intensity, sound and ultrasound and light in the physics section, only light persists and is included as a topic in the section on universe in 2010, thus broadening the place given to astronomy. A small part of the 2010 health topic concerns periodic signals in terms of physical principles and their derived medical applications (ultrasound, endoscopy, ECG). Finally, some basic mechanical concepts – mechanical actions, principle of inertia, pressure – added in 1999, are kept in 2010 and shared between the topics of universe and sport. In chemistry, the 1992 themes (chemistry in fields and gardens, chemical elements of the world and the universe, oil and natural gas) enabled discussion of concepts of the atom and chemical species, as well as chemical transformations, in industrial contexts related to agriculture and energy sectors. In 2010, these very same notions, spread into the three 2010 topics, are assumed to be more familiar to pupils. Thus, within each topic, chemistry and physics sections (not reported as belonging to one or the other) alternate, juxtaposed and with no interaction.

2.16. Globalisation in SVT

In the 2010 SVT programme, the choice has been made to address a range of different topics and therefore not to elaborate too much on them. These topics are grouped under three themes. The first one is about the uniqueness of planet Earth on which life develops. In 2010 it discusses the characteristics of living beings and their phylogenetic relationships. The second one focuses on the environment (soil and water) and takes on global dimensions including, in particular, energy issues. The third theme relates to the physiology and functioning of vertebrate organisms and focuses on muscle function in humans. In the 2010s, this theme incorporates a health component, whereas in 1993 it is oriented on nervous and hormonal communication.

The main themes addressed by SVT programmes have remained remarkably stable for 20 years in the 'Seconde' programme, especially regarding geological aspects. Changes mainly concern scales at which processes are observed. A very significant example is photosynthesis. In 1992, it is described as a very detailed process at the organ level or cellular level, and in 2010, as a global process concerning the entire planet. This introduces the consideration of energy balance in the biosphere and societal aspects such as bio-fuels and food issues

(production, supply, diets, etc.). Similarly, human-orientated themes tend to include health and sustainable development educational aspects.

2.17. Competency-based approaches

The concept of competency, officially introduced into French general education in 2006, corresponds to a combination of fundamental knowledge for our time, abilities to implement in various situations but also indispensable attitudes throughout life. Its gradual deployment, at all school levels, is associated with those of the 'démarche d'investigation' (investigative approach) and other teaching methods ensuring the development and evaluation of its various components, such as the 'tâche complexe'. In 2010, the official programme is organised in a table with two columns: a list of 'knowledge content' and a list of 'minimum competencies' in PC and 'abilities & attitudes' in SVT.

Nevertheless, competencies were already mentioned in the 1992 PC programme in a specific column named 'minimum competencies' in which competencies and knowledge content were mixed. In SVT, only in the preamble a few general terms such as 'developing mastery of the experimental approach', or 'aquiring a rational attitude' are hinted at as competencies.

2.18. Distancing from techniques

References to research and industrial activities are very numerous in the chemistry part of the 1992 PC programme. The aim is to introduce pupils to practices rooted in scientific research – to observe, analyse, and measure – rooted in industrial practices – to design and manufacture – and to train citizens – wise uses and consumer choice of chemicals. The physics part of the programme aims to be a 'science and technology guide' by articulating technical applications and research practices.

In 2010, the breakaway with techniques is clear: the item 'initiation practices and methods of experimental science' raises but few technical developments, except implementation of experimental protocols. Competencies focused on intellectual processes – questioning, reasoning, critical thinking, language competencies – already present in 1992, come to the fore in 2010. Science is a way of thinking (and no longer a way of doing). In SVT programmes, references to techniques are not as explicit as in those of PC, the breakaway is less clear. In 2010, as in PC, the same type of competencies are highlighted as well as the understanding of the nature of scientific knowledge and its mode of construction.

2.19. Removal of technical/natural objects

In 1992, the inductive approach is advocated by some members of the experts group (Duverney 2006). Teaching is rooted in the study of technical objects. Under the headings 'contents' and 'competencies', about sixty different objects can be enumerated. They range from simple objects (springs, beads), to everyday technical systems (Hi-Fi, walkman, television). They belong to different reference fields: industrial applications (ultrasound, X-ray, sonar, UV lamp), measuring instruments (oscilloscope, multimeter) and body parts (ears, eyes). In chemistry, the main reference fields are engineering approaches and industrial processes (extraction, synthesis, distillation, catalytic cracking & reforming); as well as numerous chemical elements and materials (ammonia, oil, plastic) implicated in these processes.

In the SVT 1992 programme, diversity of the living world and of living environments is a strong topic but we never find names of particular species. Types of organisation are rarely quoted (vertebrate, invertebrate), and the same applies to organs (leaves, nerves) structure (ganglion), cell types (neurons), organelles (chloroplasts) and cellular components (proteins), mineral (sand) or organic (humus) soil components, and finally geological structures (volcanoes).

In 2010 PC, specific objects have totally disappeared from the heading 'contents'; only concepts, models, laws, and some generic objects (molecules, chemical species, solids, gases) remain. In the 2010 SVT programme, descriptions and specifications are much less precise than in 1992. For instance, a comparison of cellular ultrastructure is mentioned with no further detail. Biodiversity is arranged into three levels: ecosystem, species and genetics. Generic terms of animal and plant species, of photosynthetic parts are used throughout the programme. Only in the section dedicated to the human body, organs (muscle, heart, veins, arteries) are mentioned.

2.20. IT Integration

In the 1992 SVTprogramme, the use of computers is associated with the same restrictions as in 2010: it is not a substitute for real experimentation, for authentic experimental activity.

In 1992, in the physics preamble, the computer, placed next to the video, belongs to modern technologies and is embedded in many activities. In the contents heading, the computer is quoted as a means to process data, in both the chemistry and physics sections. For instance, Fourier analysis and sound synthesis software programs are recommended in the music acoustics section.

In 2010 in both programmes, IT is present in all sections and headings: CAT (Computer-assisted experimentation), simulation, but also documentary research and activities. It is also a strong support in all kinds of educational technology such as interactive whiteboard use and ENT. Some class activities may lead to the validation of IT items necessary to obtain a computer science and Internet certificate (B2i -Brevet informatique et internet). However few specific software programs such as 3D molecule visualisation software are mentioned in the Seconde programme while many software packages need to be mastered at the end of upper secondary school.

2.21. Towards common approaches

The scientific approach.

Preambles in 2010 PC and SVT programmes share some identical lines about experimentation, located in the 'experimental approach' paragraph for PC – next to the scientific method paragraph – and located in the 'investigative approach' paragraph in the SVT programme. This highlights the different views these programmes have on the role and interrelationships between scientific and investigative approaches as well as experiments.

Thus, in 2010 PC, an entire paragraph is devoted to the scientific approach and the experimental approach. The scientific approach involves going back and forth between inductive and deductive reasoning as well as between theoretical modelling and experimental verification. The wording differs quite substantially from the inductive approach advocated in 1992. PC instructions focus on determining the conditions of validity of a model. The possibility is created for the pupil to respond to a 'situation problème', by setting up a problem-solving task, including a protocol explained by an articulation using the investigative approach, an idea which is not formulated in PC but is developed in SVT.

The scientific approach, as described in SVT, entails a broad formulation and testing of hypotheses. This approach can be constructed from experiments, observations, parameter measurements, modelling or simulations. A major change between 1992 and 2010 is the significant drop in the share allocated to observations.

Investigative approach in SVT

The investigative approach ('démarche d'investigation') is a pedagogical approach amply described in SVT. Starting with a situation arousing curiosity, an outline of steps including a formulation of hypotheses, design of a testing

strategy, comparison of results and assumptions; and finally the formulation of knowledge that can be easily remembered. The investigative approach does not necessarily include experimentation; it can be built on observations, analysis of documents, as well as historical documents ('démarche d'investigation historique'). By contrast, in 2010 PC, the investigative approach is not detailed and is just mentioned in an isolated sentence at the conclusion of the scientific approach paragraph.

2.22. Expanding documentary activities

In 1992 the physics programme gives a central role to experimental activities. Even if there are already examples of documentary activities in both physics (5) and chemistry (8) sections, "activities" remain largely of the experimental-type – 27 in physics and 21 in chemistry. In 1999, document activities are clearly displayed alongside "experimental activities" under the heading 'suggested activities'. In 2010, documentary research is cited in the ICT paragraph. Under the heading 'competencies', examples are scarce and nearly all refers to experimental activities (22). Among, the only examples of documentary activities, one is explicitly titled analysing scientific papers on the observation of the solar system but provides very vague wording.

In the 1992 SVT programme, in relation with scientific investigative approaches, documentary and bibliographic research activities, observations or uses of experimental setups are all at the same level of importance, even though very few examples are given. This compares sharply with the 2010 programme where for the great majority of knowledge contents (90%) the corresponding 'capacities & attitudes' items can be mobilised in documentaries activities, such as 'identify, extract and organise information'.

2.23. Citizen & critical thinking development

In 2010 PC, scientific and technical culture is a lower secondary school prerogative when the upper secondary school education focuses on scientific and civic culture. The programme quote Daily life scientific activity and technological development can be interpreted as related to social and civic issues for which training pupils in critical thinking shall help them to become concerned citizens in the future. Interestingly, 'science', in the singular, is considered a structuring educational tool rather than a subject of study in itself. The use of science in the singular is widespread in 2010 while it was very rare in 1992.

2.24. History of science

While in PC, the two programmes stress the importance of history of science; no reference is made to this topic in the 1992 SVT programme. In 1999, in a common preamble for upper secondary education, historical presentation is highlighted for its invaluable cultural value and because it helps to assess the struggle humanity has faced to solve problems. In 2010, a specific allocation of time is given to the teacher to use history of science as a tool to understand the nature and structure of scientific knowledge. The teacher is invited to consider the historical approach as a distinctive way to carry out an investigative approach.

In PC 1992, the programme instructs to refer to historical perspectives and the evolution of ideas to help pupils build their own coherent representation of the universe. In 2010, the emphasis is stronger; a full paragraph is devoted to history of science, invoking educational and moral reasons (inspire intellectual freedom [...] and the will to persevere) as well as cultural and social approaches. It shows that modern science is universal and that it transcends cultural differences and is for the good of humanity. There is no direct connection with investigative approaches; this differs sharply from SVT where a distinctive approach called 'démarche historique d'investigation' is recommended.

2.25. Linking art and science

In 2010, a new link is recommended with the humanities and arts in PC or art history in SVT. In PC, the programme suggests that science is a door to the beauty of the laws of nature hence demonstrating a close link with the humanities and the arts. It also suggests studying the perspective of art on science and technology and the relationship between art and innovation. In SVT, linkages with art history are suggested through literary and pictorial evocations of biodiversity as well as Greek and Latin statues of human bodies in the sports topic.

2.26. Pedagogical freedom on the rise…

In 2010 SVT programmes, an entire paragraph is dedicated to the issue of pedagogical freedom. In 'Seconde', and in contrast with the rest of the upper secondary education, teachers are offered a significant degree of liberty in regards to the depth of argumentation and knowledge content as well as pedagogical approaches. Such liberty is strongly restrained by the general didactic principles, which are precisely detailed in the programme (competencies, investigative approach, ICT, historical investigative approaches, introduction to complexity, field works, autonomy, teamwork and evaluations). In PC, this matter is only mentioned, in a few lines, at the very end of the programme. In both 1992 SVT and PC, no reference is made to pedagogical freedom even though both

programmes underline that activities are only suggested whereas knowledge contents are mandatory; similarly, the order of presentation is suggested in physics and SVT but mandatory in chemistry.

3. Discussion: Summary of convergences between textbooks and school subjects

The comparative analysis of SVT and PC textbooks between 1993-1996 and 2010-2014 reveals some converging trends in both school subjects.

In SVT, references to living organisms become more generic (e.g. invertebrate instead of giraffe) hence warding off SVT both from being a 'leçon de choses' (a relegated approach of the natural sciences, in which observation has a central role) and from a vision of the living world as a complex web of singular organisms. School subjects' restriction to model organisms leads to a generalist and universalist vision of biological processes. As Jacques Monod says 'what is true for E. coli is true for the elephant' (Monod 1961).

In 1992 PC, the programme offers many studies of various objects which all converge to a reduced set of simple and universal laws describing their physical properties. In 2010, the further narrowing to the study of a single exemplar object as the sole illustration of a given physical phenomenon appears as a climax of this principle.

From a linear approach to contents and a narrow and detailed outlook of studies' objects (Bonnéry 2015), school subjects tend to offer a broader view, both more synthetic for PC and more holistic for SVT. This broader view moves away from measuring instruments and objects and shifts towards experimental and analytical approaches. In SVT, this is exemplified by the introduction of the 'tâche complexe' approach and by referring to scientific issues on a global level. In PC, this is exemplified by the emergence of historical approaches supported by increasing documentary activities in textbooks. Interestingly the scope of SVT expansion is more spatial, when it is more temporal in PC, stressing the historical perspective. This is not directly related to the evolution of programmes over time: later historical approaches are prescribed in SVT and reservations are expressed regarding investigative approaches such as the 'tâche complex' in PC.

The documentary approach has been used for over thirty years in the teaching practices of SVT, which explains the convergence of approaches in both SVT textbooks and programmes; while documentary approaches are hardly referred to in PC programmes.

Should we conclude that the practice of documentary activities is sufficiently recognised among teachers and thus also among textbook writers so that it does not need to be explicitly recommended; or does it rather reflect the discomfort that PC teachers may feel when faced with activities far removed from traditional physics teachings methods?

However, does this ambivalence between approaches (presence or absence of answers to questions, feasibility or not of the proposed experimentation) reflect the ambiguity of these multi-recipient textbooks?

When, in activity sheets, experiments are designed to be carried out in the classroom without including results, it relates either to direct use in the classroom or as a guide for the teacher to get pupils to brainstorm. On the contrary, when experiments and results are fully described, it is both a source of information and explanation to pupils and a ready-to-use resource for the teacher. In the 2000 programme reform, the issue has been resolved in a radical way for PC: these sheets were removed from pupils' textbooks and added to teachers' textbooks.

Another significant change, specifically for physics, is the programme segmentation by topics instead of disciplinary specialties. Such an approach has been continuously in use for chemistry since 1992, where subjects taught in chemistry were connected to industry and research sectors. However, neither programme redactors nor textbook writers have succeeded in presenting the full PC programme by topics in an articulated way. This presentation only succeeded in giving a unified perspective of both fields, without addressing interdisciplinary matters or illustrating specific contributions of physics or chemistry to a given topic (e.g. health).

Similarly, connection with other school subjects, scientific or not, recommended by the programmes has hardly been implemented in the textbooks. Furthermore, the topical approach paradoxically limits connection with other school subjects as it reduces the scope of examples to one topic. For instance, in 1996, lessons on sounds and ultrasounds are not limited to echography as it is in 2010, but animals, musical instruments and sonars are also studied.

Going back to the selection process of the corpus, for a given publisher, textbook writers differ from one discipline to another, and from one period to another. The discontinuity in the panel of publishers selected for our study between 1993 and 2014 has had little impact on our results. However, we found out that significant changes in organisation and presentation have taken place between the first and

second edition of the same textbook. It was interesting to have a second edition (Belin 2014) in our corpus to strengthen and confirm identified trends.

Confirming and explaining these trends, as well as checking how they are specific to a given level, can be carried out through the examination of textbooks and programmes for the previous and following years. In the following levels (Première, Terminale) in the science series, teachers favour approaches that are used for exams. For instance, the ‘tâche complexe’-type approach has been part of the exam (Bac) since 2013 and has naturally led teachers and students to practice these in the classroom; as a consequence the second editions of textbooks readjusted their content to take into account not only the usual user feedbacks but also the informal evolution of the curriculum. Conversely, activity-based pedagogy and the topic approach are linked with lower secondary education practices. The ‘Seconde’ level is paradoxically closer to the lower education levels as it is not yet specialised. In that context, the dissemination of practices in place in lower secondary education level is significant and is set to be amplified with the imminent implementation of EIST (integrated science and technology) in the first level of lower secondary education (starting 2016).

Our assessment of ‘Seconde’ textbooks through analysis of the layout, structure and content underlines the tensions that influenced their design.

Textbooks, described as "composite written materials" (Bonnéry 2015), do not simply present and organise knowledge contents; they also reveal the specificity of each type of activity and manage the presence of heterogeneous items, whilst evidencing their overall consistency. Use of structuring elements as well as navigation tools – internal or external – are on the rise, leaving less room for scientific contents.

Thus PC and SVT textbooks look more and more like organisational proposals or a year plan for the level and discipline, with segmentation of content as well as level of details. All of the studied dimensions and their identified evolutions enable a better understanding of the usage or non-usage of these textbooks by teachers.

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