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Marty, L, Venturini, P, & Almqvist, J. (2017). Teaching Traditions in Science Education in Switzerland, Sweden and France: a comparative analysis of three curricula. *European Educational Research Journal*. https://doi.org/10.1177/1474904117698710

Teaching Traditions in Science Education in Switzerland, Sweden and France: a comparative analysis of three curricula

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Abstract

Classroom actions rely, among other things, on teaching habits and traditions. Previous research has clarified three different teaching traditions in Science Education: the academic tradition builds on the idea that simply the products and methods of science are worth teaching; the applied tradition focuses on students' ability to use scientific knowledge and skills in their everyday life; and the moral tradition opens up a relationship between science and society, focusing on students' decision making concerning socio scientific issues. The aim of this paper is to identify and discuss similarities and differences between the Science curricula in Sweden, France and Western Switzerland in terms of teaching traditions.

The study considers the following dimensions in the analysis: 1) The goals of science education as presented in the initial recommendations of the curricula; 2) The organization and division of the core contents; and 3) The learning outcomes expected from the students in terms of concepts, skills and/or scientific literacy requirements.

Although the three traditions are taken into account within the various initial recommendations, the place they occupy in the content to be taught is different in each case. In the Swedish curriculum, our analyses show that the three traditions are embedded in the initial recommendations and in the expected outcomes. On the other hand, in the Western-Swiss and French curricula, the three traditions are embedded in the initial recommendations but only academic tradition can be found in the expected outcomes. Therefore, the Swedish curriculum seems to be more consistent regarding teaching traditions.

This may have some consequences on teaching and learning practices, which will be discussed in the article. Moreover, our analyses enable us to put forward definitions of teaching tradition.

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Keywords: comparative didactics, teaching traditions, didactic transposition, curriculum, science education

Introduction

Through the implementation of curriculum recommendations, teachers in different countries are expected to teach different kinds of content and to use various ways of teaching. Even though we can expect many differences between the intended curriculum, the implemented curriculum and the attained curriculum (Houang & Schmidt 2008), the intended curriculum gives some characteristic shape and direction to teaching practices and may influence students' learning and socialization in the classroom (cf. Lundqvist et al., 2012).

In this article, we compare science curriculum texts from three European countries (France, Sweden and Western Switzerland) corresponding to lower secondary school (children aged 11 to 15) in order to understand what is taken for granted about teaching and learning in each country - but also to discuss questions of differences and similarities among countries. The overall aim of this paper is to identify communalities and specificities between the science curricula in the three countries and to analyse them in terms of teaching traditions.

This study forms part of a larger research project ("Teaching traditions and learning. Comparative didactic analysis of science education and physical education and health in Sweden, Switzerland and France") that aims to compare science education and physical education teaching practices in secondary schools within different educational contexts, to refer them to one or more particular teaching traditions and to identify the limits of, and the possibilities for learning offered by, different teaching traditions. For science education, the project focuses particularly on the comparison of physics teaching practices in lower secondary schools. The comparative analysis of curricula in this paper is part of the comparative analysis of teaching practices that will be conducted with the tools of comparative didactics as developed in the French-speaking field of educational research (Ligozat, Amade-Escot & Östman 2015; Ligozat 2011; Mercier, Schubauer-Leoni & Sensevy 2002) and in the Swedish didactical tradition of research on teaching traditions, learning and socialization (cf. Englund 1998; Lundqvist et al., 2012; Östman et al., 1998).

First, we introduce the two facets of our framework (didactic transposition and teaching traditions) which form the basis for the comparative analysis of the curricula. Afterwards, we present the general features of the science education curricula at lower secondary level in the three countries and we introduce some criteria for analysing them in order to find the teaching traditions embedded in the texts. We then show our results with a special focus on the physics curricula as an illustrative example. The discussion provides insight into the implications for science teaching.

Analytical Framework: Didactic Transposition and Teaching Traditions

In the French "didactiques", the organization and content of the curriculum is regarded as a result of a transposition process (Chevallard 1988, 1985/1991; Chevallard & Bosch 2014). This theory relies upon a praxeological definition of "knowledge", which states that knowledge is embedded into the institutional practices of the various social groups that create or use it for specific purposes in society. Consequently, it is possible to identify bodies of knowledge as networks of techniques and discourses based upon the techniques - in which core concepts may have different meanings depending on what kind of institution they are used in. For example, a scientific concept such as energy, voltage, etc. can be conceptualized differently according to whether it is used in an engineering social group or an academic one. This is what Chevallard termed "the ecological approach to the social dynamic of knowledge" (2007).

> [Bodies of knowledge] have to be transformed, deconstructed, reconstructed in order to adapt to their new institutional setting. For instance, the mathematical objects used by economists, geographers, or musicians need to be integrated in other practices commonly ignored by the mathematicians who produced them (Chevallard and Bosch, 2014, p.171).

Consequently, bodies of knowledge (as praxeologies) used in different activities may share a family resemblance but, in all cases, they are original constructions that fit the institutional purposes of the social groups in which they are used.

The educational system is a specific institution dedicated to the transmission of the culture that is needed for the young generation to act adequately and purposively in various social groups and activities. Bodies of knowledge that exist in the school system are packaged specifically for the purposes of teaching and learning. In particular, they are shaped by some specific constraints (division into subjects, time restrictions, assessments, etc.). The didactic transposition constitutes the set of transformations that the bodies of knowledge used in society undergo to fit the specific constraints of the educational system (Verret 1975; Chevallard 1985/1991).

The actual curriculum is a result of changes in relation to previous curricula and influences by current social needs and political decisions:

> Society as a whole, i.e. society expressing itself through its culture, must first recognize the supposed body of knowledge as teachable knowledge.(…)[Otherwise], the teaching system will be accused of being cut off from the rest of society- from the so-called real world (…). It will be charged with arrogantly ignoring the needs of society (Chevallard, 1988, p.9).

Consequently, different visions for science education are formulated by different social groups (cf. Robert 2007a, 2007b; 2011). The final formulation of a curriculum text is a political compromise reached among various groups and interests (Englund 1998; Östman 1996). In science education, the building of the curriculum is a process that relies upon the current institutional practices involving scientific knowledge. These scientific practices may take place within academic institutions that produce scholarly knowledge, within engineering institutions such as applied research laboratories, or within institutions that deal with socio-scientific issues such as consumer associations or environmental organizations.

The choice of the scientific practices regarded as composing the reference for what will be taught in the classroom has important consequences for the curriculum content. In particular, the goals assigned to science education are influenced, in different ways, by the purposes of the scientific practices it is derived from. Research on science curricula has shown some patterns concerning the purposes of science education as embedded in the curricula, which have led to the formalization of a typology in terms of *teaching traditions* (cf. Lundqvist et al., 2012; Östman 1998; Roberts 1998). In education within each tradition, the teaching focuses on the use of science in a specific manner:

- The Academic Tradition (AcT) focuses on scientific products or processes.
- The Applied Tradition (ApT) focuses on practical issues related to science and how scientific knowledge can be applied to them.
- The Moral Tradition (MT) focuses on moral, social, economic or political issues and how scientific knowledge can be applied to them.

Depending on tradition, scientific concepts, theories and models are used in different ways. For example, the scientific concept of energy would be embedded in one specific practice within the academic traditions, namely the disciplines of science. Used in the moral tradition, on the other hand, it would be used as a resource to solve some kind of problem. It would still be the concept of energy that would be in focus, but used in a different manner.

General Presentation of the Science Curricula

In each country considered, the knowledge-to-be-taught (Chevallard, 1991) in compulsory school is communicated to the teachers through official curriculum texts : the “Programmes de l’école et du collège” in France (primary-and-lower-secondary-school curriculum), the “Läroplan för grundskolan, förskoleklassen och fritidshemmet 2011” in Sweden (Curriculum for the compulsory school, preschool class and the recreation centre 2011) and the “Plan d’étude romand” in Western Switzerland (Western Swiss Study plan).

In the French lower secondary school, science education is organized as three subjects: “Life & Earth Sciences”, “Physics & Chemistry”, and “Technology”. Implemented since 2009, the French curriculum is national. The curriculum text for the subject “Physics & Chemistry” is structured in three parts: an “introduction” common to mathematics and all science subjects; a “preamble” specific to the subject “Physics & Chemistry” and the core contents that are presented as a three-column table (the scientific topics scheduled for the 3 years of lower secondary school, the skills that students are supposed to learn regarding each topic and some guidance for teachers). The whole curriculum text for “Physics & Chemistry” extends over 26 pages, 12 of which are devoted to the “introduction” and the “preamble”. The parts before the core contents, which are usually dedicated to overall goals will be called “initial recommendations” in this paper.

In the curriculum from 2011, Swedish science education is organized into “Biology”, “Physics” and “Chemistry” for all compulsory classes (from primary school to the end of lower secondary school). As for all other subjects, the Swedish “Physics” curriculum text has a three-part structure, covering: the “aim” (common for all compulsory levels); the “core contents” (including a division into teaching topics) and the “knowledge requirements” (for each grade). The whole curriculum text for “Physics” extends over 6 pages, 1 of which is devoted to the initial recommendations.

Since 2010, the French-speaking states of Switzerland have had a common curriculum for all the compulsory school levels. In science education, the division into subjects is somewhat different from the French and Swedish ones: “Natural & Technical Phenomena”, “Diversity of Life”, and “Human Body”. The curriculum text for the subject “Natural & Technical Phenomena” is in two parts: first, some “general comments” that are common to mathematics and all science subjects and then the core contents, including a progression for learning the scientific topics, some expectations regarding students’ skills and some guidance for teachers. The whole curriculum extends over 11 pages, 4 of which are devoted to the initial recommendations.

Table 1 summarizes this general presentation and provides some complementary information about the structure of the various curricula.

Physics Education Curriculum Text in…	France “Physics & Chemistry”	Sweden “Physics”	Western Switzerland “Natural & Technical Phenomena”
Initial recommendations	“Introduction” ➢ Common to mathematics and all science subjects ➢ For lower secondary	“Aim” ➢ Specific to Physics ➢ For all compulsory levels	“General Comments” ➢ Common to mathematics and all science subjects ➢ For all compulsory

	school levels "Preamble" ➢ Specific to "Physics & Chemistry" subject ➢ For lower secondary school levels		levels
Core Contents	Three-column table (including a division into teaching topics) : - "Knowledge" - "Core Skills " - "Comments" for teachers	- "Core Contents" (including a division into teaching topics)	- "Learning progression" (including a division into teaching topics) - "Pedagogical guidance" for teachers
Learning outcomes	"Knowledge" and "Core Skills" (1st and 2nd column of the table of core contents)	"Knowledge requirements" for each grade (A, B, C, D and E)	"Basic expectations"

Table 1 : Structure of the Physics curricula in France, Sweden and Western Switzerland

From this first general level of description, we can draw three preliminary conclusions about the similarities and differences among the curricula:

First, Switzerland and Sweden have the common feature of presenting a consistent division of subjects for all compulsory levels, although the designation of the subjects differs between the two countries. In Switzerland, the subjects are labelled in such a way that the links with the academic subjects are eclipsed ("Natural & Technical Phenomena", "Diversity of Life", and "Human Body") whereas, in Sweden, the links with the academic disciplines are obvious ("Biology", "Physics" and "Chemistry"). This difference in designation is far from trivial. Since the subjects related to biology are twice as numerous as the subjects related to physics, chemistry and technology in Western Switzerland, the time allocated to the teaching of biology ("Diversity of Life" and "Human Body" taught to 11 to 13 year-olds) is twice the time allocated to the teaching of physics, chemistry and technology ("Natural & Technical Phenomena" only taught to 12 to 13 year-olds).

Second, in France, there is a clear split between primary and lower secondary school curriculum texts and the division into subjects in relation to the academic fields only occurs from the lower secondary school ("Physics & Chemistry" "Biology" and "Technology").

Third, depending on the country, the initial recommendations target science teachers more or less broadly. In France and Western Switzerland, the goals assigned to the subject "Physics & Chemistry" or "Natural & Technical Phenomena" are shared with those assigned to mathematics and the other natural sciences whereas, in Sweden, the goals assigned to "Physics" are specific to the subject matter in question, even if closely related to the goals for Chemistry and Biology.

Research Questions and Methodology

All the different demarcations presented below may affect how students see the place of Physics within science but also the place of scientific knowledge in relation to other kinds of knowledge. Hence, each curriculum, specific to each national context, reflects a specific didactic transposition in the manner in which the subjects are divided and what is included or left out. In order to explore the didactic transposition processes that has taken place in each country in greater depth, we will identify and discuss further similarities and differences in curricula between the three countries and analyse them in terms of teaching traditions.

Adopting a comparative approach enables us to shed light on what is taken for granted in a specific educational practice (cf. Almqvist & Quennerstedt 2015; Ligozat, Amade-Escot & Östman 2015). It may be difficult for a researcher who belongs to a particular culture to recognize salient features of her/his own curriculum and practices. The use of a comparison (i.e. the analysis of common and specific trends) makes it possible for the researcher to step back from her/his own cultural references and to see not only her/his own curriculum but also other curricula in a new light.

In order to conduct the comparative analyses, we needed to find some features common to all three countries. We thus suggest considering the dimensions noted in Table 1 since they all emerge in the three curricula despite some differences in designation: 1) The goals of physics education as presented in the initial recommendations of the curricula; 2) The organization and division of the core contents into teaching topics and 3) The learning outcomes expected from the students in terms of concepts, skills and/or scientific literacy requirements.

Results

The goals of physics education as presented in the initial recommendations

Despite the difference in lengths, organizations and contents in the parts devoted to the “initial recommendations” for each curriculum, there are no major differences in the purposes assigned to physics education in the three countries.

First, one of the goals emphasized in the three sets of initial recommendations is that science education is supposed to provide tools (concepts, models, theories) for the students, in order to support their understanding of nature and to help them in making sense of the surrounding world. For example, explaining how rainbows occur using the laws of optics fulfils this goal.

- In the French curriculum: “At the end of lower secondary school, students should have built an initial comprehensive and coherent representation of the world in which they live. (…) Experimental sciences and technology enable them to better understand nature and the world built by and for humans”(MEN, 2008, p.1)
- In the Swedish curriculum: “Teaching should contribute to pupils’ familiarity with the concepts, models and theories of physics, as well as an understanding of how they are shaped in interaction with experiences from studies of the surrounding world” (LGR 11, p. 120)
- In the Western-Swiss curriculum: “[The Mathematics and Natural Sciences domain] provides the students with intellectual tools to grasp and understand reality and to come to terms with it.”(MSN, PER, 2011, p.7)

These goals are connected to the academic tradition because they support the idea that what is worth teaching is the set of tools internal to sciences (concepts, models, theories). Furthermore, they may also be related to the applied tradition provided that these tools are meant to be applied to the surrounding world. In this case, they may expand the students’ insights into events occurring in their everyday life and shed new light on familiar phenomena that were not previously seen through the filter of “scientific explanation”. However, since there is no explicit focus on problem solving in these citations (other than students’ understanding of the world), we would stress that they are closer to the academic tradition than to the applied.

A second kind of goals concerns the relationships between science education and socio-scientific issues that arise out of school: science education is supposed to help students to understand and possibly to form an opinion on controversial issues related to science and technology, such as climate change or the energy crisis. For example, giving some clues to help students analyse the media discourse when it is about global warming could fit within this goal.

- In the French curriculum: "[Mathematics and Natural sciences] also have the purpose of enabling the students to understand the social stakes of sciences and technology." (MEN, 2008, p.1)
- In the Swedish curriculum : "Teaching in physics should essentially give pupils the opportunities to develop their ability to use knowledge of physics to examine information (…) and take a view on questions concerning energy, technology, the environment and society." (LGR 11, p.120)
- In the Western-Swiss curriculum: "In a society strongly influenced by scientific and technological progress, it is important that everyone own basic tools allowing her/him to understand what is at stake in the choices made by the community, to follow a debate on such grounds and to be able to grasp its main stakes. "(MSN, PER, 2011, p.7)

Since these goals focus on understanding the choices made by the community about science-related issues, they belong to the moral tradition.

According to the third category of goals, science education is supposed to support the students in becoming aware of the consequences of their daily-life decisions whether on an individual level (health, safety, etc.) or a collective one (natural environment, community, etc.). For example, the understanding of how smoking affects our own health or how recycling waste impacts the environment could fit within this category.

- In the French curriculum: "Some ethical questions which should be approached early are gradually introduced: What is the right thing to do? On what reasonable and sharable grounds? What responsible attitude should one have regarding the living world, the environment, our own health and that of others?" (MEN, 2008, p.2)
- In the Swedish curriculum: " Pupils should be given the preconditions to manage practical, ethical and aesthetic situations involving choices that concern energy, technology, the environment and society " (LGR 11, p.120)
- In the Western-Swiss curriculum: "By questioning the world around them, one aims at making them aware of the consequences of their actions on their environment."(MSN, PER, 2011, p.7)

The ability to make a reasoned and conscious decision in situations of everyday life is based on several factors: for example, the decision to quit smoking could be motivated both by purely scientific arguments (link between smoking and cancer) and by moral/social ones (the desire to preserve family health or to prevent the community from health expenses in case of illness related to smoking). Therefore, these goals are relevant both in the applied and in the moral tradition.

Finally, the last kind of goals found in the three curricula concerns science education as a help to students in developing their reasoning skills and critical thinking.

- In the French curriculum: "Teaching should also help to develop students' critical thinking."(MEN, 2008, p.9)
- In the Swedish curriculum: "Teaching should contribute to pupils developing their critical thinking over their own results, the arguments of others and different sources of information" (LGR 11, p.120)
- In the Western-Swiss curriculum: "[Mathematics and Natural Sciences] contribute to the development for the students of a *Reflective Approach* notably by (…) developing their critical view on their own choices and/or results and on those of others, by leading them to renounce run-of-the-mill ideas about understanding natural or mathematical phenomena (…) " (Modélisation, MSN, PER, 2011)

Critical thinking is a cross-functional skill: it is not restricted to a particular subject area or manner of teaching. For this reason, this goal goes beyond any particular teaching tradition. It is relevant to teach these skills within all the traditions, even though the aim and content of critical thinking may be different in each.

In the three curricula, these four categories of goals cover most of the ideas developed in the initial recommendations. However, we can find some other, minor purposes, especially in the French and Western-Swiss curricular texts. For example, they both promote the fact that science education may also support written and oral skills in French language. Furthermore, both curricula refer to cross-sectional topics that teachers are expected to teach in addition to the core contents.

In France, the curriculum defines some “convergent topics” (thèmes de convergence) that are common to several subjects forming the “wider scientific field” (mathematics, physics & chemistry, biology, technology, history and geography, citizenship education, physical education). The convergent topics are: energy, environment and sustainable development, meteorology and climatology, statistical approach of the scientific world, health and security. Teachers of all subjects are supposed to work together to provide students with coherent tasks around these topics.

In Western Switzerland, the curriculum states that all subjects (including “Natural & Technical Phenomena”) should be taught in relation with cross-sectional topics such as "Health and Wellbeing", "Media, Image, Information and Communication Technology", "Interdependencies, social, economic, ecological", "Living together and practice of democracy" or "Personal projects" . All these topics are defined in detail in a specific section of the curriculum text.

To sum up, the core goals of the three curricula as they are presented in the initial recommendations appear to be quite similar. According to these objectives, the students should be able

- to explain the events of the natural world using scientific concepts and scientific methods;
- to realize the impact of daily-life science-related decisions at both individual and collective levels ;
- to understand the ins and outs of issues involving collective decisions about science-related social issues ;
- and to exercise their critical judgement by discriminating facts from values and taking a step back from unfounded statements.

Most of these goals can be directly linked to one or several teaching traditions (academic, applied or moral tradition). All of the teaching traditions are represented in the initial recommendations of the three curricula.

Organization and division of the Physics core contents into teaching topics

In the three curricula texts, the core contents that follow the initial recommendations are subdivided into teaching topics, which we analyse in this section.

In the French curriculum, since the core contents are given in great detail for each level, we will take the example of a particular level (children between 14 and 15 years old) that is indicative of the core contents as a whole. At this grade, the three topics to be taught are: “Chemistry, science of matter transformation”, “Electrical Energy & AC circuits” and “From Gravitation to Mechanical Energy”.

In the Western-Swiss curriculum, the teaching topics are common to all years of lower secondary school: “Matter properties”, “Optics”, “Mechanics”, “Electricity” and “Energy”.

In the Swedish curriculum, the teaching topics are common to all years of compulsory school : “Physics in Nature and Society”, “Physics in Everyday Life”, “Physics and World Views“ and “Physics, its methods and way of working“.

The way the core contents are divided into teaching topics shows meaningful dissimilarities between the French and Western-Swiss curricula on the one hand, and the Swedish curriculum on the other. In the first two, the organization of the core contents is related to academic fields of reference (even if the actual content of these topics may have only family resemblance with the academic practices). In the last one, the logic of the structure is different. The boundaries of teaching topics are organized differently and, at first glance, some of them seem to overlap. For example, “Physics in Everyday Life“ may also be regarded as “Physics in Society“ in some ways but, in the curriculum, they are set apart. Nonetheless, the organization of the core contents seems to put science in its context and to put more emphasis on the relationship between science, daily life and society. In other words, this organization suggests that the institutions regarded as references are not limited to academia.

Learning outcomes expected from the students in terms of concepts, skills and/or scientific literacy requirements

In the three curricula, the learning outcomes expected from the students are expressed in various ways: in the French curriculum, the second column of the table included in the core contents features “the core skills” that students are supposed to develop regarding each scientific topic. In the same vein, the Western-Swiss curriculum mentions the “basic expectations” of students’ work regarding each scientific topic. In the Swedish curriculum, there is a specific section devoted to the “knowledge requirements” that comes after the core contents section and that concerns all teaching topics. These are the various learning outcomes that we will study in this section.

In the French curriculum, the excerpt we have chosen to show here deals with the study of Ohm's law by 13- to 14-year-olds. It is typical of what can be found in all other parts of the curriculum:

> Topic: "Ohm’s law"
>
> Core Skills:
>
> - Suggest or implement a protocol to address Ohm's law.
> - Measure [voltage, current or resistance] (estimate the accuracy of the measurement and optimize measurement conditions)
> - Suggest a suitable representation to show that the current in a circuit is directly proportional to the applied voltage (table, voltage vs current graph…)
> - Express Ohm's law in a correct sentence.
> - Express Ohm’s law with a mathematical relation
> - Use Ohm’s law formula (MEN, 2008, p.20)

This part of the French curriculum is oriented towards the understanding of abstract scientific ideas and concepts. For example, here, science teaching should make students able to experiment Ohm's law and, above all, to establish connections between all its semiotic representations (formula, table, graph, sentence).

It is noteworthy that the physical world is barely mentioned here and, when it is, it is seen through the filter of theories ("a protocol to address Ohm’s Law"). Furthermore, the physical world implied in this extract is set up especially for science education (rheostat, low-voltage power supply, etc.) and is not connected to the everyday world that students are familiar with.

It is then quite clear that such expectations regarding students' outcomes falls within the academic tradition since it focuses on the products of science and stresses abstract and theoretical knowledge with no direct application to problems outside the disciplines of science.

In the Western-Swiss curriculum, the chosen excerpt concerns 14- to 15-year olds and is about the properties of matter. Once again, this excerpt is typical of what can be found in all other parts of the curriculum:

> Topic: Properties of Matter
>
> Basic expectations: During, and at least at the end of the cycle the student …(…)
>
> - …. uses a molecular model to interpret the characteristics of the states of matter
> - …. uses a molecular model to interpret and forecast the evolution of physical phenomena: dilation, diffusion within liquids and gases, temperature changes
> - … makes a distinction between physical transformations (phase transition) and chemical transformations(combustion)
>   … explains conservation of mass by way of conservation of atoms, without using a chemical reaction model, in the cases of water electrolysis and of simple combustions involving only the elements carbon, oxygen, hydrogen and iron
>   - … uses the chemical reaction model to explain mass conservation (MSN, PER, 2011, p.40)

The Western-Swiss curriculum is oriented towards the use of scientific models; science teaching should make students capable of establishing the link between the physical world and the models that describe it. Like the French curriculum, the Swiss one obviously belongs to the academic tradition but, additionally, it contains items that could possibly be connected to the applied tradition. The physical world that is mentioned in the extract seems more related to the everyday world than the French one was: for instance, "diffusion within liquids and gases" may be the diffusion of perfume in a room or the diffusion of a food dye in a glass of water; the "simple combustions involving only the elements carbon, oxygen, hydrogen and iron" may be the burning of a candle or the combustion taking place within a car engine. Consequently, depending on which kind of experiment the teacher chooses to emphasize, students may have the opportunity to apply scientific concepts to events that are familiar to them. For this reason, the Swiss curriculum leaves open the possibility that both the academic and the applied tradition exist in the classroom. However, the only tradition that is explicitly mentioned in the text remains the academic one.

The Swedish curriculum expresses its learning outcomes more broadly than the French and Swiss ones since it is common to all teaching topics:

> Knowledge requirements (for grade A at the end of year 9) [14- to 15-year olds] :
>
> - Pupils can talk about and discuss questions concerning energy, technology, the environment and society, and differentiate facts from values and formulate their views with well-developed reasoning (…)
> - Pupils can carry out studies based on given plans and also formulate simple questions and planning that can be systematically developed. (…) Pupils can compare results with their questions and draw well developed conclusions with good connection to the models and theories of physics. (…) Pupils can apply well developed and well informed reasoning where phenomena in daily life and society are linked together with forces, motion, leverage, light, sound and electricity (…) In addition, pupils apply well developed and well informed reasoning about how people and technology affect the environment and show, from different perspectives, the advantages and limitations of some measures that can contribute to sustainable development (LGR 11, p.129)

The Swedish curriculum is oriented towards the tangible benefits that may be derived from science teaching, such as the ability to describe, give examples, explain, communicate, conduct investigations, create texts, or debate science topics. Like the French and Western-Swiss curricula, the academic tradition has an important place in this text, through reference to products and activities specific to science. However, unlike the situation in the French and Western-Swiss curricula, the world outside of the classroom is explicitly mentioned repeatedly ("questions concerning energy, technology, the environment and society"; "phenomena in daily life and society"). In fact, one of the expressed outcomes of science teaching is to enable students to see the link between events of daily life and society and the models and theories of physics. The applied tradition therefore seems to be well represented in this text.
Furthermore, the emphasis placed upon discussion and debate of social issues related to science ("the advantages and limitations of some measures that can contribute to sustainable development") shows that specifications related to the moral tradition are also embedded in the curriculum.

Conclusion

From these results, we can draw some conclusions about the similarities and differences among the curricula:

First, we can see a split between the salient features of the French and Western-Swiss curricula on the one hand, and the Swedish curriculum on the other.
In the Swedish curriculum, the learning outcomes expressed in the part about "knowledge requirements" meet the goals of science teaching as presented in the initial recommendations. Furthermore, the way the curriculum is divided into teaching topics strengthens and expands this consistency to the whole curriculum. According to all sections of the curriculum, the students should be able to apply scientific concepts and scientific method to the surrounding world, to understand the consequences of science-related issues at both individual and collective levels, and to exercise their critical thinking and reasoning skills. In conclusion, references to all teaching traditions (academic, applied, moral) can be found throughout the curriculum.
In the French and Western-Swiss curricula, the learning outcomes expressed in the part about "core skills" or "basic expectations" do not meet the goals of science teaching as presented in the initial recommendations. Furthermore, the division of the curriculum into teaching topics tends to increase the gap between the initial recommendations and the rest of the curriculum. In the initial recommendations, the goals assigned to science teaching are the same as in the Swedish recommendations: in addition to academic knowledge, an understanding of the ways in which science, society and technology interrelate are emphasized. Finally, the learning outcomes are much more limited since they only focus on developing the ability of students to learn the products and processes of science itself and fail to mention the world outside the science laboratory. In conclusion, all teaching traditions (academic, applied, moral) can be found in the initial recommendations but only one of them (academic tradition) is mentioned in the learning outcomes.

Consequently, the academic tradition is the only tradition consistently represented in the French and Western-Swiss curricula. The central position of the academic position within these curricula may have several implications for students' learning and socialization in the classroom, especially on student's motivation and vision of nature, science and the relationship between them.

Finally, the Swedish curriculum is the only one that consistently promotes an applied and moral outlook in science teaching. However, the curriculum has some grey areas as to what is expected from teachers regarding the implementation of these traditions. In particular, outstanding issues concern the nature of science-related needs for everyday life at the core of the applied tradition and the new means of assessment required by the moral tradition.

All these points will be discussed further in the section below.

Discussion

<u>The gap between initial recommendations and learning outcomes in the French and Western Swiss curricula</u>

There is a gap between the goals of science education as presented in the initial recommendations and the learning outcomes of the French and Western-Swiss curricula, especially in comparison with the strong consistency of the Swedish curriculum. In particular, the moral tradition, which is well represented in the initial recommendations, seems to disappear from the rest of the French and Swiss curricula.

However, this split between initial recommendations and core contents does not necessarily show a lack of consistency in the educational system in a wider sense. Both educational systems are inspired by the writings of Condorcet, among other things, and these were fully in line with the ideas produced by the French Enlightenment (Kintzler 1984; Hofstetter 1998). According to Condorcet's theory of "Public Instruction" (Instruction publique), the overarching goal of schooling is to train students to use their own reasoning by providing them with scientific, philosophical, literary and historical knowledge. The idea is that they can later build their own moral point of view from this knowledge and participate in public debates. In this view, the school system is not expected to teach any particular political or moral standpoints; it limits itself to giving students a set of intellectual tools that will form the basis for their autonomy and empowerment as citizens:

> [According to Condorcet], the school system should be independent of any political power or pressure group from civil society. It should not seek immediate usefulness (…).The transmission of knowledge, which is the responsibility of the Public Government prevails over the moral education that should remain a private business. (Eliard, 1993, p.59-60).

Condorcet made the distinction between "public instruction" and "education": "Public instruction is based on the use of Reason, while education belongs to the domain of moral, political and religious values" (Massot 2002, p.8). He stated that only the first one falls within the school's prerogatives. This view was the main inspiration for the founding values of "the republican school" throughout the 19th century in France and in Western Switzerland (Buisson 2012; Dubois 2002), even if the success of its implementation is still subject to debate (Lelièvre 2002; Hofstetter & Perisset Bagnoud 1998).

Therefore, if we consider that the current French and Western-Swiss curricula result from an evolution of previous ones, there may be no gap between their initial recommendations and their learning outcomes since they do not express the same thing: while recommendations talk about the overarching teaching purposes, the learning outcomes focus on the specific scientific tools acquired in the school year, which, when added to all the tools provided over the years in other subjects, will help to form citizens that are able to think critically by themselves. Some quotes from the French curriculum may support this interpretation:

> Understanding the close relationships between living conditions and living forms, as well as the influence of men on these relationships, **gradually leads** to better understanding of man's place in nature and **prepares** students to think about the individual and collective responsibilities in the field of environment, sustainable development and biodiversity management (MEN, 2008, p. 3).

> The teaching of physics and chemistry is involved in the construction of a 'guidebook of science and technology' so that students can understand and **later** take part intelligently in the political, social and ethical choices (MEN, 2008, p. 10) [emphases added]

According to this reading of the curricula, thinking about "the individual and collective responsibilities [towards] the environment" or the students' ability to participate in a debate involving "political, social or ethical choices" is not the direct responsibility of the science teacher. These aims are considered as overarching purposes of teaching and learning through all school subjects.

In conclusion, the gap between the goals of science education as presented in the initial recommendations and the learning outcomes of the French and Western-Swiss curricula can be construed as an attempt to reconcile new educational demands from modern European societies and the historical roots of French and Western-Swiss school systems based on the thinking of Condorcet.

Finally, this does not automatically mean that science teaching in France and Western Switzerland is completely disconnected from socio-scientific issues but rather that these debates do not enter the classroom via the core contents of the curriculum. They may be brought in through individual teachers' teaching and especially through some pilot research projects (Brossais & Panissal 2013; Monge & Pellaud 2015). If and how science teachers in the three countries investigated here work with these ambitions in their teaching practices is an empirical question that goes beyond the scope of this article, but which we will tackle later in our project.

<u>The central position of academic tradition in the French and Western-Swiss curricula</u>

The academic tradition is the only tradition consistently represented in the French and Western-Swiss curricula. In recent decades, the benefits for learning arising from the central position of the academic tradition within science curricula has been called into question.

First, it has been argued that only a small percentage of students benefit from learning academic science, since its main objectives concern the training of the next generation of scientists (scholars, engineers, physicians, etc.) (cf. Roberts 2007). Solomon (1998) makes the distinction between "academic scientific culture" that "must be cultivated so that the whole edifice of scientific knowledge is accessible to (…) [future] science scholars" and "popular scientific culture" in which "science needs to be learned in order that everyone can appreciate new developments and can evaluate them for their own and others' style of living" (p.176). Therefore, a subsidiary question concerns the differentiation of the curriculum (Millar 2012). Should science curriculum designers provide two curricula, one that targets future scientists and provides the first stages of training in science, and another one that aims at developing wider scientific literacy? What should be the connection between the two curricula, given that (i), as Robert puts it, "everyone agrees that students can't become scientifically literate without knowing some science" (Roberts 2007, p.11) and (ii) that future scientists are future citizens as well and should not be excluded from learning the interrelationships between science and society?

Second, since the academic tradition focuses on abstract and theoretical ideas, the experiments introduced by the teacher, if any, are intended to illustrate these ideas and are often created specifically for science education (e.g. a block sliding on a frictionless table, a simple gravity pendulum, etc.). Hence, students are expected to commit to situations very different from their daily-life experiences without knowing whether they benefit from their learning in other contexts outside school. This doubt is likely to lead to a loss of interest from many students, widely identified in the scientific literature. In the Nuffield Foundation-funded report about science education in

Europe, Osborne & Dillon (2008) state that school science “lacks of perceived relevance“ and that it is “often presented as a set of stepping-stones across the scientific landscape and lacks sufficient exemplars that illustrate the application of science to the contemporary world that surrounds the young person“ (p.15).

Third, all traditions, including the academic one, embed companion meanings that accompany the teaching of science and “are communicated both explicitly and implicitly, by what is not said as well as what is said” (Roberts 1998). These companion meanings constitute a set of coherent messages addressed to students and reflect norms and values about science, about nature and about the relationship between human beings and nature (Östman 1998). By ignoring the social issues raised by science, the academic tradition fails to take the consequences of scientific development on humans and the environment into consideration and promotes the idea that any new scientific discovery automatically means progress. Östman (1996) states that, according to this point of view, “the human being stands above nature and we use nature as an instrument” and “since nothing is said about our responsibility for our interactions with nature, (…) human beings are rulers over nature with no moral obligations” (p.48). In other words, the lack of ethical and moral reflection on scientific output that characterizes the academic tradition paves the way to a positivistic and scientistic companion meaning communicated to students in the classroom.

The limits of academic traditions and the development of socio-scientific issues have encouraged science educators to find other ways to teach science, giving rise to new traditions (applied and moral traditions).

<u>The applied tradition through a view on science-related needs for everyday life</u>

The Swedish curriculum is the only one that consistently promotes an applied view of science teaching over the whole curriculum. However, implanting a curriculum based on an applied tradition raises some questions. This kind of curriculum requires teachers to reflect in depth about the needs of citizens in terms of scientific knowledge and scientific skills: in what circumstances do citizens need to use scientific knowledge to solve a problem of their daily lives? Although Fensham stated, as early as 1988, that “the rote call of a number of facts, concepts and algorithms are not obviously socially useful” and that we should “allow obvious social usefulness to determine what scientific information should be learnt”, the obviousness of the science-related needs has turned out to be difficult to appreciate and, in fact, this issue is still far from settled in the current literature. There is a part of the research in science education that advocates that a science-related need to solve practical issues does not exist at an individual level: “We all live surrounded by [technical] objects of which we do not understand the working principles, without actually feeling a need to know” (Johsua 2002, p.180). Other studies highlight very unpredictable patterns in the potential needs of citizens in terms of scientific knowledge. For example, Feinstein (2010) reviewed several studies on the subject, which showed that, in situations where science could be expected to be relevant (elderly people planning their heating budgets, parents of children with Down’s syndrome, etc.), “people did not think of their problems in terms of science”(p.174) and in contexts “where few people expect science to be relevant” (students in high poverty urban environments), “each student found science useful in a different way”(p.176).

In science education, therefore, a challenge that the teachers (and textbook authors) face if they follow the aims of the applied tradition is to consider if and how they make students deal with and prepare for situations relevant in everyday-life, science-related issues (cf. Hamza et al., this issue). They will also need an understanding of what kind of knowledge the students may need in the future (cf. Aikenhead et al., 2011).

Furthermore, even in practical issues where science is indeed involved, people may be able to deal with the issue using their own kind of knowledge that does not overlap with concepts of academic science. Johsua (2002) gives the example of the "public utility people who have very precise knowledge about the proper way to lift containers" (p.178) without using any academic references. In the same vein, a chef making mayonnaise can talk about the quality of the emulsion, which, is the term used in academic knowledge but, here, is grounded in a very specific way within the culinary expertise of the chef. Feinstein (2010) reached the same kind of conclusion when he wrote that "laypeople become involved in science [when] they develop their own knowledge and expertise" (p. 179) and quoted Miller (2001) saying that "while scientists may have scientific facts at their disposal, the members of the public concerned have local knowledge and an understanding of, and personal interest in, the problems to be solved" (p.178). So it seems that people may be able to develop local knowledge that has a family resemblance to academic knowledge without overlapping with it and that enables them to solve some practical issues related to science.

In science education, therefore, another challenge that the teachers (and textbook authors) may have to face if they refer to the applied tradition is to check whether they introduce concepts of academic science in situations where local knowledge and expertise would be the real and effective way to address the practical issues related to science in everyday life. Consequently, they will need to be aware of differences in the use of language in different situations, for example scientific practice and everyday life (cf. Olander 2009 ; Säljö 1998).

<u>Assessment in a curriculum promoting a moral outlook on science teaching</u>

The Swedish curriculum is the only one that consistently promotes a moral outlook on science teaching over the whole curriculum. However, implementing a curriculum based on a moral tradition also raises some questions, especially about the assessment of students' knowledge and the relation between teachers and students.

In authentic socio-scientific debates, there are different kinds of arguments that are contributed by different kinds of institutions. Let us take the socio-scientific issue concerning nuclear power, for example. In that case, there are several institutions allowed to take part in the debate: the institutions that provide power and electricity, the institutions that promote environmental rights (such as Greenpeace), the institutions that represent the people who will potentially live near the nuclear plant, etc. These various organizations put forward a wide range of reasons why nuclear power should be promoted or suppressed. These reasons include scientific, political, social, legal and economic arguments. Ultimately, the choice between different points of view has to be justified on moral grounds, involving a perspective on what a modern society should be like, in terms of balance between individual needs, collective needs and protection of the environment. In other words, socio-scientific issues are necessarily value-laden (cf. Sadler 2011).

In science education, if the aim is to implement socio-scientific issues in the classroom, there might therefore be several obstacles for science teachers and students: the fact that socio-scientific issues are value-laden and complex makes it necessary for teachers to think about their teaching and assessment practices (Almqvist et al., submitted; Orpwood 2001, Sadler 2011). For example, the Swedish curriculum states that teachers are expected to teach students to "take a view [i.e: form an opinion] on questions concerning energy, technology, the environment and society". Given that Verret (1975) advocated that a body of knowledge is teachable only if it can be assessed, this raises the question of what can be assessed about the item: "taking a view". If the teacher chooses to directly assess the viewpoints expressed by students, this raises an ethical issue since any kind of argument in such a debate is still open and unresolved, and the only way to decide if one argument should prevail over another is to weigh the underlying values. Assessing viewpoints would then be no different from assessing moral values.

In the research field of Education for Sustainable Development, a discussion is in progress about this (Östman et al., this issue) and a central part of this discussion concerns socio-scientific issues (Tytler 2012). For example, the moral tradition can be divided into two different (sub)traditions in this article: the normative and the pluralistic traditions. Briefly, in the normative tradition, teachers expect students to learn pre-defined norms about science and how they are supposed to be used in solving environmental (and other) problems. This is also what we warned about above (cf. Sund & Wickman 2008). Proponents of the pluralistic traditions, on the other hand, highlight and accept different views and argue for the importance of open and rational discussions in the classroom (Englund et al., 2008, Hedefalk et al., 2015, Rudsberg & Öhman 2010).

If the teacher chooses to assess not the viewpoints but how well the students argue, then the assessment is shifted towards the quality of argumentation. Several comments can be made about this shift: first of all, in a socio-scientific issue, the logic of argumentation may not rely only upon scientific knowledge but also on reflections based on well-being, emotions, aesthetics, etc. Consequently, the teacher assesses arguments that go beyond the scope of science as a subject.

Furthermore, argumentative skills are traditionally at the core of French/Swedish Language as a school subject. For instance, in the lower secondary school curriculum texts of the "Swedish Language" subject, students should be taught to "lead a conversation, formulate and respond to arguments"; to analyse "the purpose, content, structure and language elements" of different kinds of texts like "argumentative texts such as newspaper articles, scientific texts, etc."; to "search for information in libraries and the Internet, in books and the mass media"; to "quote and make references to sources, to sift through a large amount of information and examine the reliability of sources with a critical perspective". The same kind of goals can be found within the "French Language" curricula in France and Western Switzerland. So, when assessing the quality of arguments, do science teachers assess the scientific validity of arguments or do they assess the same argumentative skills that are already assessed in another school subject?

Finally, there may also be several challenges from the students' perspective in situations where they deal with a socio-scientific issue. First, concerning the assessment, it may be difficult for them to know exactly on what grounds they are assessed. Consequently, they may customize their opinion according to what they think is expected of them in order to have a good mark. For instance, they may shape their views so that they meet perceived expectations of the teacher or views prevailing in mainstream media. Additionally, arguments on a socio-scientific issue go beyond the scope of traditional academic disciplines of science and may refer to sensitive subjects. Consequently, it may be difficult for students to participate in a debate and express ideas about subjects they are not familiar or comfortable with.

Conclusion

The theoretical framework in terms of teaching traditions used to make the comparison of the French, Swedish and Western-Swiss curriculum texts has enabled us to highlight noteworthy tensions within the curricula. First, in France and Western Switzerland, the various teaching traditions are not given the same importance in all sections of the curriculum text: the discourse in the initial recommendations offers a comprehensive range of teaching traditions while the core contents only focus on the academic tradition. Second, the various teaching traditions are not given the same importance in all the countries in question: the applied and moral traditions are highlighted more and in a much more consistent way in the Swedish curriculum texts than in the French and Western-Swiss ones. It is likely that that these differences have significant implications for teaching practices.

The second step of the research concerns the comparative analysis of science teaching practices. The conclusions about the tensions identified in the curricula form the basis for this comparative analysis since they enable us to focus on some relevant aspects of the practices. First, we will be interested in how the teachers weigh up the varied sets of requirements from the different sections of the curricula (initial recommendations and core contents). Second, since all teaching traditions were found to varying degrees in the three curricula, we will aim to compare, through the analyses of teaching practices, what is implemented with respect to what is stated in each country, given the potentialities and constraints of the teaching traditions set out above.

Acknowledgements

Funding: This research was funded by Grant No. 2012-5023 from the Swedish National Research Council.

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