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CRITICAL ANALYSIS OF POPULARISATION DOCUMENTS IN THE PHYSICS CLASSROOM: AN ACTION RESEARCH IN GRADE 10

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Abstract

Critical work on popularisation resources is a widely recommended activity, one considered to motivate students and prepare them to be responsible citizens. This investigation explores the extent to which some activities aimed at this goal can be fruitfully organised in the classroom, in the course of an ordinary syllabus, at grade 10 level. Two expectations orientate our research: in this context, students presented with written popularisation documents would tend to limit their comprehension of the core message to what is directly connected with their syllabus; and they would not easily evaluate the respective importance – in terms of comprehension – of the implausible elements used in the document to facilitate its reading. After a preliminary investigation with teachers and students, a teaching-learning sequence was designed on the basis of our expectations, completed by the hypothesis that three specific aspects of students' learning processes would be mutually resonant in a "virtuous circle". The implementation of this sequence for three successive years (N_t=94 students) with the same teacher provides stable results. Beyond analysing to what extent the outcomes support our expectations (to a rather large extent, in fact) we discuss the value of the elements within the "virtuous circle" to orientate the analysis of student learning processes in this type of classroom interaction.

Key words: *popularisation resources, school-oriented reduction, critical analysis, teaching physics, didactic.*

Introduction

It is commonly advocated that students should be put in contact with presentations of scientific knowledge that are used in non-formal education, such as popularisation journals or other media, or museums (an extensively documented question: e. g. Allen, 1997; Goodlad, 1973; Jacobi, 1987). Motivation is one of the arguments used; another is that it develops their ability to benefit from such sources, which includes improving their critical sense, where the perspective is life-long education. Numerous investigations are available concerning the benefits to be expected from such extra-scholastic means in an extracurricular context. By contrast, using these in the classroom (for instance Gil-Perez, D. & Furio-Mas, C.J. 1984) is a less documented field, although some recent projects aiming at developing "Scientific literacy" (Hunt, R. & Millar, R. 2000, Burden 2005, Millar 2006) provide noticeable results in terms of feasibility, or of students' and teachers' views about the experimented course. As Millar (2006) writes: "[after having implemented the evaluated programme] teachers perceive the scientific literacy emphasis as markedly increasing student interest and engagement. Key challenges identified are the language and reasoning

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demands in looking critically at public accounts of science, and the classroom management of more open discussion about science related issues". These comments concern a complete project – one clearly oriented towards science literacy. Several authors (Wellington 1991, Jimenez & Federico-Agraso 2007, Mantsouridis *et al.* 2007) also stress the need for a mutual fertilisation between critical work on popularisation resources and more traditional school activities. Here, we aim to report in detail on students' reactions to particular teaching strategies inserted in the course of a traditional syllabus. We sought to document the common practices and attitudes with respect to teaching-learning activities about popularisation materials, in this case, written documents intended for Public Understanding of Science ("PUS-docs" in the following). Our investigation was conducted with teachers and with students at grade 10 level – that is, in the last year in secondary school before the students decide whether or nor to specialise in science.

Rationale and Research Questions

Our general perspective is that, beyond bringing to bear the supposedly engaging features of such documents, the activities under study aim at generating intellectual satisfaction in students (Viennot 2006). By that, we mean the pleasure of understanding a topic to a given extent, one that can be relatively well specified, and produced at an acceptable cost in terms of time, a definition used by Mathé and Viennot (2009). Intrinsic to such an approach is an appreciation of the large extent of consistency and predictive power of physical theories (Ogborn, 1997, Jenkins 2007). Such is our angle of attack regarding the "key challenges" enunciated by Millar. It is worth noting that, in so doing, we leave aside a large part of what is often looked into, concerning students' ability to criticise public accounts of science. Indeed, as has been argued by Jiménez-Aleixandre (2006) and Erduran and Jiménez-Aleixandre (2008) concerning critical analysis, several components can be envisaged. One has been referred to the idea of "commitment to evidence" (Siegel, 1988). A different component is the ability to criticise the sources of the texts under consideration with respect to possible asymmetric relationships of power. Clearly, this second component, or in other words a critical analysis of the status of experts (Walton 1996, see also Habermas 1981), is not included in our perspective, nor do we consider other abilities such as those listed by Jiménez-Aleixandre and Puig (2009).

In our investigation, the goal envisaged for teaching-learning activities about popularisation materials is to develop a view of the topic under study that is as consistent as possible, on the basis of the document analysed.

Our first research question seeks to evaluate the impact of two possible difficulties as regards this goal.

Concerning the first of these difficulties, we expected that, given the institutional frame chosen for the planned activities, we were to observe – in students as well as in teachers - a tendency in reading the proposed documents that we call a "school-oriented reduction". It consists in reducing the main message of a document, or what might be done in class concerning the document itself, to what is directly related to the academic syllabus or to activities that are ritual in class.

As regards the second difficulty, we expected that students were, to a non-negligible extent, open to pinpointing the simplifications and / or implausible elements present in nonschool documents ("facilitating element / potential obstacle" or "FEPO": see Feller *et al.* 2007). But we also anticipated that students would find it difficult to estimate whether these FEPOs were consequential as concerns the reader's comprehension, and – more difficult still – to organise them in a hierarchy from this standpoint.

In this paper, we document the question as to whether, and if yes to what extent, these two expected difficulties affect the students and their teachers before any teaching or training. We also report on the intellectual processes and achievements in this respect that were observed in students during and after the teaching-learning sequence that we designed accordingly. In Leach and Scott's (2000, 2002) words, the "learning demand" for these activities consist, in particular, in

overcoming the two limiting processes just described.

Our second research question strongly contributed to the design of this sequence. We hypothesized that there existed a resonance between several aspects of the targeted teaching-learning processes. We put forward the hypothesis that there exists a "virtuous circle" comprising several components in synergy (see *fig. 1*): a better understanding of the main message of the document under analysis facilitates the elaboration of a hierarchy among the FEPOs, which in turn helps the students deepen their conceptual understanding of the broached domain, and the whole process generates intellectual satisfaction. Our second research question is an attempt to evaluate the validity of this hypothesis.

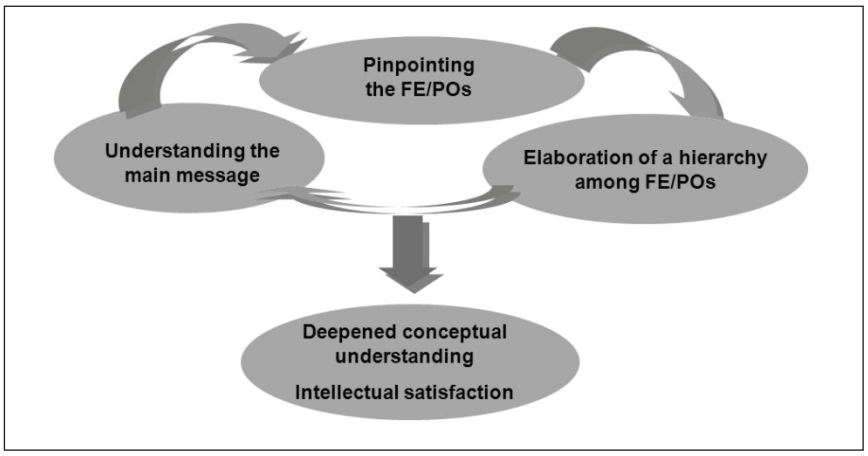

Figure 1. "The virtuous circle".

Clearly, metacognition is involved in this part of our investigation, in line with the viewpoints expressed, for instance, by Champagne, Gunstone and Klopfer (1985) or Baird (1986, 1990). We have collected comments expressing students' views on their own intellectual activities during the TLS3 sequence. It is worth noting that, given that our hypothesis of a "virtuous circle" excludes a linear causality, such a metacognitive activity is to be seen as a targeted outcome of the teaching-learning interaction as well as a possible factor of conceptual progress. In terms of content, we do not evaluate conceptual achievements besides a comprehension of the main message of each document. As Gunstone (1994: 145) argues, "one aspect of content appropriate for the achievement of metacognitive purposes is that it is neither already understood nor totally unfamiliar". From this standpoint, the extent to which the broached topic is unfamiliar to students is likely to be a relevant parameter of the teaching-learning situation.

When analysing the students' level and reasons for satisfaction during and after the sequence, we made particular reference to this hypothesis of a "virtuous circle". We looked for clues pointing to a difference in this respect depending on whether the students intended to specialise in science, or not.

Global Structure of the Investigation

After a first exploratory investigation about the use of popularisation resources, we chose to focus our investigation on the use of written non-academic documents in the classroom, as a possible support to a conceptual activity. More specifically, these documents comprised at least one image and aimed at explaining a topic. We researched the *a priori* views of students and teachers concerning this type of work, at grade 10 level. On the basis of this preliminary investigation (PI: Feller 2008), we designed a teaching-learning sequence in line with Meheut and Psillos' definition (2004), for the same level. The corresponding teaching time is about 4 hours, spaced out over the

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school year. This sequence ("TLS3") relies on the analysis of three documents (PUS-docs). The students' reactions during the three corresponding sessions and their global judgement at the end of the sequence were analysed. The experimentation with the sequence has been repeated three successive years with the same teacher who is also the first author of this paper. About 30 students were concerned each year.

Each phase of this investigation is described below in more detail, and the main results are discussed.

Exploratory Investigation and Preliminary Inquiry (PI)

The hypotheses presented above and the corresponding research questions were chosen and refined on the basis of a first exploratory work (Feller 2008). This phase of our work consisted in particular of written questionnaires posed to teachers (experienced: N=23, first year of practice: N=14) and students (N=68) of the same profile as those involved in the subsequent investigations, with general questions about the use of popularisation resources. From these very first clues, we found that PUS resources were considered positively by the pupils and by the teachers. The educative potential of such material was well acknowledged. However, it seems, judging by the sample we tested, that the pupils do not spontaneously consult PUS resources and that the teachers do not incite them to do so. Finally, it seems that a classroom activity involving a PUS-document is extremely rare. Moreover, questionnaires (N=14) and interviews (N=5) before and after museum visits – an activity that is much in favour and more frequent – provided clear clues of a school-oriented reduction: The school activities suggested by the teachers revolved almost exclusively around the concepts approached on the current syllabus, to the detriment of a more global understanding of the various issues tackled. We were also insistently asked by the consulted teachers for some means which would enable them to choose educational objectives and appropriate strategies for these museum visits.

After this first exploratory work, we conducted our preliminary inquiry (PI), based on three documents which, according to our first estimation, are in line with Gunstone's suggestion: Their contents are neither utterly strange nor totally in accordance with what the pupils are currently taught. With written questionnaires (more detail below), we documented pupils' (N=128) and teachers' (N=33) reactions and comments concerning the meaning and the merits of each document. The results are very similar to those that we obtained afterwards, with the same questionnaires and with other pupils, in the introduction to each session of TLS3 sequence.

The school-oriented reduction – previously observed with museum visits - turned out to be also present in teachers' and pupils' comments about the three documents that we used.

Thus, with the first document (Doc1), all of the teachers seemed to share this tendency when they suggested to present students with questions exclusively focused on a concept of the current syllabus. As for the students, most of them tended to refer the meaning of each document to the understanding of a concept already taught in class, to the detriment of a global understanding of the document. This phenomenon was still more frequent with the second document (Doc2), which is more complex both conceptually and from the standpoint of image composition.

The school-oriented reduction, which constitutes our first expectation, was thus observed clearly in this preliminary inquiry. It might be that, when facing a particularly complex document, students tend all the more to resort to the safety of this limited approach.

Concerning our second expectation, we found that the consulted teachers were, spontaneously, uncritical of the proposed documents, although once they were asked to focus on possible implausible elements or simplifications, they easily found some. The students, by contrast, provided a great deal of criticism regarding the analysed documents. But all of the criticisms formulated seemed to be on the same level. Neither the students nor the teachers commented on the relative risks – in terms of reader comprehension – entailed by each implausible element (FEPO) that they pinpointed. The risks of misunderstanding supposedly linked to these FEPOs, therefore, do not seem to be commonly ranked in a hierarchy.

More globally, while the teachers as well as the students express the view that the proposed documents are engaging, the students, in a non-negligible proportion, do not seem to be satisfied with this attractive effect. They often express the need for a deeper understanding, a fact that fits in with our hypothesis of the "virtuous circle".

Principles and Basic Tools for the Design of the TLS3 Sequence

Given our preliminary results, we considered it necessary to closely accompany the students in their path towards a fruitful critical analysis of the proposed documents. As said in the introduction, the reference for this analysis is the accepted physical theory, with its great extent of consistency and predictive power.

The same three paper documents already used in our preliminary investigation (with other students) were used in this sequence. In this paper, for the sake of brevity, we present only the first document (Doc1) in relative detail. The two others can be found on-line (Feller 2008: 405-407).

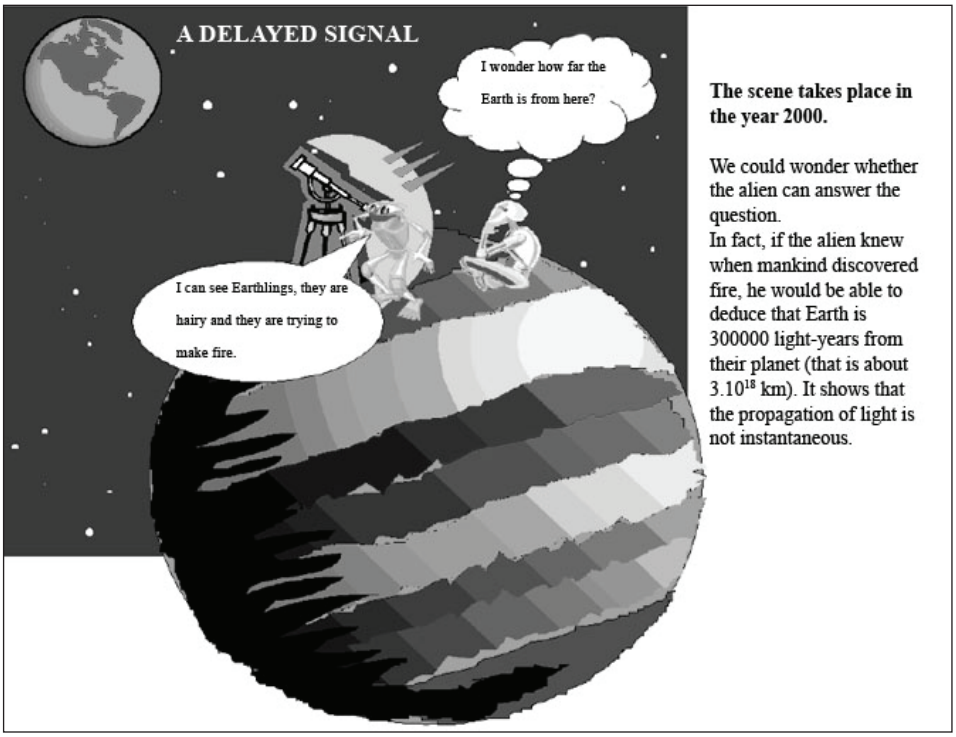

Figure 2. The first document, Doc1, about extraterrestrials ("ETs").

When trying to determine the students' understanding of the main message of this document, we chose the reference meaning as follows: *The speed of light being finite, a signal carried out by light reaches us with a time delay.*

Just before our intervention, the students had been taught the orders of magnitude concerning the universe. Therefore, we expected that some of them would understand this document merely as an opportunity to calculate the distance between the planet and the Earth. An answer of this type constitutes, for us, a clue to a "school-oriented reduction".

Moreover, there are clearly some simplifications or implausible elements (FEPOs) in this document.

Among such FEPOs, we consider the following likely to be detected by students in grade 10:

- The existence of extraterrestrials and the fact that they speak French
- The size of the ETs with respect to their planet
- The incredible power of the telescope
- The size of the Earth

All of these "FEPOs" do not entail the same risks of misunderstanding. They range from a funny caricature to a suggestion that ruins the very consistency of the document.

Considering the size of the ETs in comparison with that of their planet, it can be reasonably thought that the students will not be destabilised by this denial of realistic scales. Also, what telescope today, at such a distance, could reveal such precise details as hairs on the skin, or the action of making fire? Can the students detect this implausibility? Among all these FEPOs, we consider that the most problematic one is the size of the Earth, which could raise a major difficulty. The Earth, supposedly observed in the year 2000 from another planet, appears with quite distinct continents, whereas the "delayed signal" observed is a scene from prehistory, which means that the two planets are at a considerable distance from each other – say about 300,000 light-years away. At such a distance, the Earth should appear as a point, granted it had sufficient luminosity. Its representation in Doc1 does not respect the appropriate orders of magnitude. This fact constitutes, potentially, a strong obstacle to the understanding of the main message.

This estimation of a hierarchy of the FEPOs in Doc1 was one of the pillars on which we designed the class work corresponding to this document.

In the TLS3 sequence, the type of critical work just illustrated is not considered in isolation. Indeed, according to the "virtuous circle" hypothesis enunciated above (fig.1), there exists in the intellectual activity of a student a synergy between the detection of the supposedly facilitating elements (FEs), their hierarchical organization in terms of potential obstacles to understanding (POs) and the understanding of the main message, the whole process laying the basis for a better global understanding and intellectual satisfaction. This is not expected to be spontaneous in students. On the contrary, we consider that this process can occur only if they are duly accompanied, that is, in an ordinary school context, under the guidance of the teacher.

The TLS3 sequence

Global features

The TLS3 sequence extends over a school year, in three sessions spaced out in the time (Table 1). This sequence was repeated over three successive years in grade 10, in the same French secondary school. This school is situated in an urban area, which is neither particularly poor nor wealthy. The rate of success in examinations is rather good (slightly above national average) without being exceptional. The proportion of students intending to choose the scientific section ranges in the national average. Each class contained about thirty pupils. The experiment concerned 94 students.

Table 1. Activities and corresponding teaching times in the TLS3 sequence.

Document	Doc1		Doc2		Doc3	
Teaching context	Class group	Half-class group	Class group	Half-class group	Homework	Class group
Teaching Time	20min	1h15	20min	1h15	-	1h
Questionnaire and / or Discussion	Q1A	Discussion 1 Q1B	Q2A	Discussion 2 Q2B	Q3A	Feedback from the teacher
Month	October	October	January	January	March	April

In order not to be invasive with respect to the syllabus of the current year, approximately 4 hours over the year were dedicated in class to all of this work. The teacher of the class implemented the sequence in continuity with the usual classroom work. Thus, this sequence was not presented as an exceptional activity. The teacher was the first author of this article.

Scenario and data collection

Each year, the sequence was organised as follows (see Table 1):

At the beginning of the year, a written questionnaire (Q1A) was handed out to students with the first document (Doc1) during a twenty-minute session, with the whole class. Two very broad questions were posed to the pupils:

- What is the main message of this document?
- Comments, criticisms, remarks?

The responses to this questionnaire were collected by the teacher, then analysed accordingto three lines of analysis:

- The identification of the main message of the document, with a possibleschool-oriented reduction
- The detection and the hierarchical organization of the FEPOs
- The students' enjoyment of the document.

These three lines of analysis echo the components involved in the hypothesis of a "virtuous circle" enunciated above.

Then, we selected a set of responses, chosen as representative of the various students' points of view. For each line of analysis, about ten responses were selected. These three sets of responses were to serve as a starting point and support for a subsequent discussion (discussion 1). Some excerpts can be found below (boxes 1, 2, 3).

The discussion was organized during the next teaching day, in half-groups. The teacher displayed on the board his selection of responses relating to the first line of analysis. The discussion successively bore on each response. This was repeated for the two other lines of analysis. During these discussions, the teacher's intervention was semi-directive. The teacher continuously reacted to the students' comments. In a progressive and adaptive way, the students' active participation was encouraged so that they gradually reached a conclusion. In the course of this collective critical process, the students had the opportunity to take a metacognitive stance, as they reacted to their own previous comments.

In about 75 minutes, the three topics were broached – identification of the main message, detection and hierarchical organization of the FEPOs, appreciation of the document.

These half-group discussions were video-taped and transcribed.

At the end of the discussion, a paper questionnaire (Q1B, more detail below) was handed out to students to assess its possible influence on students' views about Doc1.

A few months later, the same scenario was implemented with the second document (Doc2).

At the end of the year, the third document (Doc3) was given as homework. It was proposed with a series of questions intended to help the student activate the "virtuous circle" in an autonomous situation.

Finally, the students were asked to express their feelings and appreciation of the physics course during the whole year, concerning various types of work: classical exercises, experimental activities, work on documents (i.e. in fact, TLS3 sequence).

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Processing data: methods

Written questionnaires

The questionnaires concerning each of the three sessions were processed by conducting a transversal thematic analysis with respect to the various questions. Indeed, in the preliminary inquiry, it was observed that the students did not answer each question precisely, but sometimes commented on a question by answering the preceding one. One possible reason is that these questions were rather unusual for these young students. We pinpointed units of meanings that could be classified with previously defined categories, whatever their place on the sheet. The categories will be specified below for each questionnaire. They echo the two expectations and general hypothesis presented above. Some of them have been regrouped in this paper, for the sake of simplification.

In the very last questionnaire, that is targeted on a global appreciation of the TLS3 sequence, students were asked to rate the interest or usefulness of various activities during the year, in particular those included in TLS3, on a scale of 1 to 5. The results have been separated according to whether the students intended to specialise in science or not, and compared with χ^2 tests.

Discussions

The group discussions played a critical role in the teaching-learning process. They were video recorded, but they do not allow a close examination of individual students' behaviour and understanding. We will provide below typical excerpts of such discussions, with our comments, in order to illustrate what we consider to be critical nodes in the students' progression, in group sessions. This qualitative report is the result of an iterative appreciation process in which all the authors participated.

Analysis of Results

Questionnaire 1A about Doc1: the main message

Categories of responses

In order to investigate students' understanding of the main message of this document, we pinpointed units of meanings that could be ranged in one of the following exclusive categories, whatever their place on the sheet:

- Reformulation equivalent to our reference
  "Given the finite value of the speed of light, a message carried out by light reaches us with a time delay."
- Response only providing the slogan learned in class
  "Seeing far away is seeing in the past" without providing a comment closer to our reference; or simply repeating the title of the document: "a delayed image".
- Response mentioning that it is possible to calculate the distance between the planet and the Earth, without any comment closer to our reference
  "We can calculate the distance between the two planets if we know when mankind discovered fire".
- Complete misunderstanding
  "This document is intended to tell us that ETs are less smart than us because it's a long time since we discovered fire …"
- Other

Results concerning the main message of Doc1

The main points that emerge from this analysis are shown in Table 2. Given the stability of the answers over the three years, we present regrouped results.

Table 2. Occurrences of responses to the written questionnaire about Doc1, for categories relating to the main message (years 1, 2, 3).

Category of response (de facto: exclusive)	Occurrences $N_T = 94$
Equivalent to our reference message	53
Slogan or title, only	10
Exclusive focus on calculation of a distance	23
Complete misunderstanding	3
Other	5

The proportion of students (53 out of 94, 60%), who seem to understand the message in conformity with our reference is very close to that (82 out of 128, 64%) observed during the preliminary investigation (PI). It shows that, even if this document was intended to facilitate understanding of delayed signals, it is not straightforward for students to understand its content properly.

In particular, about a quarter (23/94) of respondents focus their response on the calculation of a distance. This fact echoes our expectation of a school-oriented reduction. Moreover, the mere repetition of a learned slogan or of the title of the document might be considered as a still more radical expression of a school-oriented reduction (10 out of 94, 11%), even if the corresponding statement is not erroneous.

The guided discussion: significant excerpts concerning the main message of Doc1

As explained above, after each of the two first written questionnaires, three series of responses given by students were selected in order to serve as a basis for a discussion in class. These discussions were closely guided by the teacher. The first theme of discussion for each questionnaire is the main message of the corresponding document. We quote in Box 1 an excerpt of the video-recorded discussion about this first theme, relating to Doc1. In the column on the right, our interpretation of the guiding action of the teacher or of the students' reactions is given for each step of the discussion.

Box 1. An excerpt of the guided discussion on the main message of Doc1. Bold fonts indicate students' responses to questionnaire 1A (previously selected); italics in the column on the left designate students' interventions.

Transcript	Our comments
Teacher: - What do you think of response 5): "**The objective of this document is to get us realise that a light-year is a very large distance**"? *Student A: - Well no, because it's to understand that the light does not arrive immediately.* T - So what do you think of the pupil's comment? Is it false?	*The teacher launches the discussion about the role of the distance between the planets in the main message.*

B- This is not the goal, it's true but it's not the main goal.	*The teacher provides students with an opportunity to make the distinction: «correct from the point of view of physics / identification of the main message ».*
T – So, what is the main goal then?	
C-Well, it's to get us understand that the light takes a certain time to reach us …	
D- In fact, it's response 2) that is correct	
T – Number 2)?: **The author is trying to get us understand that the arrival of light is not immediate, because the extraterrestrial who lives in year 2000 sees an image of prehistoric Earth**. What do you think of that?	*The teacher seeks to check whether the group agrees with this idea.*
All- Yes!	*Collective agreement.*
T - Yes indeed, this answer, we can say it's correct. And so now we are interested in response 6): **The author is trying to get us understand that thanks to the speed of light we can calculate distances**. What do you think of response 6)?	*The teacher points out that we can calculate the distance but that it is not the main message of the document. Final checking about response 6.*
E- True, but that's not what the document says. The objective, it's, as we said before, we see the Earth with a time delay. There, it's just another topic.	*This student sums up the intended conclusion.*
T – And, thanks to the speed of light, we can calculate distances, true?	
All: -You bet! Yes!	*Collective approval*
T -It's true, but it is not the objective of the document.	*The teacher repeats the intended conclusion.*

This excerpt suggests that the students easily identified the main message. Some of them very quickly realised that the calculation of a distance was not the main objective of this document. A short discussion was sufficient to reach a consensus or at least, the absence of any objection, whereas, previously, about 40% of these students (see Table 2, lines 3 to 5) had had difficulties when individually answering the first questionnaire.

Getting the students think about their previous responses seems to have somewhat helped them overcome the school-oriented reduction. However, this assumption relies only on a collective discussion, which leaves open the possibility of an individual and tacit resistance.

Questionnaire 1A about Doc1: the FEPOs

As said above, at the very beginning of the TLS3 sequence students were presented with the written questionnaire 1A about Doc1, the results of which have just been reported concerning the main message. We now report on the students' critical analysis of this document and of possible implausible elements (FEPOs) there.

Categories

The students' responses were classified in six categories listed and instantiated below:

- The Earth is represented as too big or too close

  "(...) however, the proportions are not respected, clearly, the Earth is too close".
  "If the Earth were at 300,000 light-years from this planet, these ETs would not be able to discern the activities of the Earthlings with a simple telescope. Moreover, at such a distance, the Earth would appear only as a spot in the drawing".
- Scales, disproportion ET/Planet

  "The drawings are bad and the ETs' size with respect to their planet is not realistic".
- Questions about of the resolving power of the telescope

  "It is impossible to have such a resolving power with an astronomical telescope".
- Anecdotal details (only two ETs, name of the planet unknown, ETs speak French, the very existence of ETs, etc.)

  "The ETs speak French".
  "There are only two inhabitants on the ETs' planet".
- General comments

  "It is easier to understand a drawing than a text".
  "The drawing is not very easy to understand without a text".
  "This document is too implicit because things are not clearly said".
- No comments or comments without any critical element

Results concerning the FEPOs (Quest 1A, Doc 1)

Here too, given the stability of the answers over the three years, the results have been regrouped (Table 3). A student may have expressed several critical comments in the same answer, therefore the numbers represent the occurrences for each category and their total number may exceed the number of students.

Table 3. Occurrences of responses to the first questionnaire (Quest. Q1A, about Doc1), for categories relating to FEPOs (years 1, 2, 3).

Categories (not exclusive)	Occurrences (N=94)
Earth: too big	9
Disproportion ETs/Planet	8
Resolving power of the telescope	11
Anecdotal details	17
General comments	59
No comment or irrelevant comment	13

We found many critical comments. Most of them (63%, 59/63) were general.

A small proportion (10%, 9/94) of the whole sample of students pinpointed the size of the Earth. None of these critical comments suggested that some implausible aspects might be more consequential for comprehension than others.

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The guided work in class with students: significant excerpts concerning FEPOs and the corresponding hierarchy, for Doc1

The excerpt of the video-recorded discussion about FEPOs quoted in Box 2 illustrates the kind of exchange that occurred and the teachers' guidance.

Box 2. Excerpts of the guided discussion about FEPOs in Doc1. Bold fonts indicate students' responses (previously selected); italics in the column on the left designate students' interventions.

Transcript	Our comments
Teacher: **– There are only two inhabitants on the ET's planet.** What do you think of this response?	*The teacher points to an implausible element (FE).*
Student A: – It's true, but it is a drawing, we are not going to represent all the people on March.	*This student considers it as anecdotal.*
T - All right. The question is to know if it hinders the comprehension of the main message.	*The teacher raises the question as to whether this is a potential obstacle (PO)?*
All – Well no, it doesn't matter!	*It is not considered by the students as consequential for comprehension.*
(…)	*(Same type of dialogue about responses 3 and 5: the teacher lets the students talk freely. The spontaneous reproduction of the process is a clue to the students' progress.)*
T – Yes, all right. Wait, I'll read: **It is not possible to see these details (the Earthlings are hairy and they are trying to make fire) with a telescope especially if we are 300,000 light-years away.** So, what do you think of this? Can this blur the main message?	
D – Well no! Scale isn't the point for the author. A big or small telescope, it doesn't make any difference.	*Spontaneously, the student turns to the problem of scales. These students seem to consider this FE as harmless.*
T – All right.	
E – Well, look at response 6). He says that the scale is incorrect. But it is in no way the purpose of the author to have appropriate scales.	*Such is the case for two other students (E, C).*
C – Yes, we aren't going to draw one planet and then the other one thousands of light-years away; there isn't enough room.	
D – In fact, this way of showing us things helps us understand.	*The student takes into account the illustrator's point of view. But the potential obstacle associated with the inappropriate scaling is not identified.*
T – All right, so, I ask you: what do you think of the student who said: we get the impression that the ETs are close to the Earth?	*The teacher tries to orientate the discussion towards the representation of the Earth.*
C – Well yes, it's the only planet that we can see with the naked eye.	
T – Well then, if we are so close to the Earth, is the light going to take 300,000 years before reaching us?	*The teacher tries to get them comment on the corresponding potential difficulty.*
D – Well no, it will take much less time.	*The student's comments suggest that the main message is understood:*
T – Then let us pose the question the other way round: if we had represented the Earth at a distance of 300,000 light-years, what would have we seen?	*Gradually, the teacher stresses the inconsistency linked to the size of the Earth.*
All – Well, nothing!	

F – A point.	
T – Then why did the author represent the Earth like that?	
G – Well it's so we'll understand that it's the Earth.	*The student underlines the reason why the drawing is like that: in order to facilitate the identification of the Earth in the image.*
T – All right, so if we draw the Earth as a point, we can understand the main message all the same?	
H – You bet we can, it is what they say that enables us to understand: I see Earthlings …	*This reason is soon challenged.*
T - All right. So, was it necessary to represent the Earth like that?	
All: – No!	
T - You told me at first: the scale isn't a serious problem. What do you think of this?	
I – Well yes, there, it does matter.	*A student concludes that, contrary to other FEs, the size of the Earth may constitute an obstacle.*

We note in two students' remarks – *"The purpose of the author …" (student E); "Scale isn't the point for the author" (student D)* – that the very concept of a main message seems to be appropriated. The argumentation effectively relies on this main message, so that the idea that the Earth should appear as a point on the image is well accepted (student F). We also observe that three students (C, G, H) consciously take some distance with regard to the immediate reading of the document. Indeed, these students mention the constrains of the illustration – here that of facilitating the identification of the Earth. In doing so, they clarify the facilitating role (FE) of the exaggerated size of the Earth. It is when this analysis conflicts with the main message that this facilitating element appears as a major potential obstacle (student I).

Working with Doc1: Assessment of students' attainments concerning school-oriented reduction and FEPOs

The possible influence of the first session on students' views about Doc1 was assessed with some written questions. These questions differed slightly from the first year to the next two, with broadly converging results.

The first year, students were asked which change they would propose in Doc1 (Quest. 1B). The data was processed as for the initial questionnaire (Quest. 1A). The categories used echo our *a priori* analysis of the FEPOs for this document. The results are summed up in Table 4.

Table 4. Occurrences of responses to a second questionnaire about Doc1 (Quest. 1B), for categories relating to FEPOs (year 1).

Suggested change: Categories (de facto exclusive) ↓	Occurrences (N_T = 29)
Size of the Earth	11
Size of ETs with respect to size of Planet	2
Other	6
No change	10

The two following years, the questions posed were exactly the same as those of the initial written questionnaire (questionnaire Q1A, about Doc 1, see above)

Table 5 displays the occurrences of responses for two categories: responses that show no reduced reading of the main message, on the one hand, and responses specifying that the improper size of the Earth is the most consequential FEPO, on the other hand. Given the stability of the results over the two years (2 and 3), they have been regrouped ($N_T = 60$).

Table 5. Occurrences of responses to the second written questionnaire about Doc1 (Quest.1B), for categories relating to school-oriented reduction and to FEPOs (years 2, 3).

Category	Occurrences ($N_T = 60$)
Main message : no school-oriented reduction	52
Size of the Earth: a major potential obstacle	16

After this first session, a large proportion of students (52/60, 87%) express the main message in conformity with our reference. This rate is higher than before teaching (53/94, 56%). It is also worth noting that, after this first session, only a small third of students (27/89, regrouping the three years) pinpointed the size of the Earth as the most consequential implausibility.

These results confirm the difficulty that we had expected concerning FEPOs. They are not in contradiction with our hypothesis that progress in this domain goes with an improved comprehension of the main message (Table 5). However, a comparison of responses before and immediately after teaching might show up the rote learning of "right answers", rather than a new critical stance.

The second session, with Doc2

For the sake of brevity, we report only on the salient features of the students' reactions to the second session.

Questionnaire 2A about Doc2: the main message

This questionnaire about Doc2 was proposed at the beginning of the second session, to the same students as questionnaire 1A (N=94).

Doc2 is more complicated than Doc1. The concepts are more difficult and the document comprises several zones of different status. On the other hand, the students had already participated in the first session, a fact that might positively influence their responses. Actually, the first of these factors seems to have been decisive:

– 83% (78/94) of the students showed difficulties in identifying the main message of Doc2.

– Spectra being on the syllabus of this class, the school-reduced interpretation consists, here, in focussing on some spectra that are shown in the document, although they are not very important nor helpful to understand the main message. Such a school-oriented reduction was observed in 37% (35/94) of the respondents.

Table 6. Impact of school-oriented reduction (focus on spectra) in students' responses about Doc2 (quest. Q2A).

Category of response	Occurrences ($N_T = 94$)
Reformulation of the message: conforms to our reference	16
Exclusive focus on spectra	35

There might be a causal relationship between these two aspects, namely, the conceptual and structural complexity of the document, on the one hand, and students' difficulties in understanding the main message on the other hand. In such a case, students might be all the more tempted to search for something approaching what they have just learned in class, thus ignoring other aspects of the document. The net result, then, would be a school-reduced reading. Our results, based on only two documents, are not sufficient to strongly support this hypothesis, but they show the relevance of putting it further to the test.

Questionnaire 2A, about Doc2: FEPOs

The students proved capable of expressing a qualitative judgment on the document. Half of them (47/94, 50%) said that they had encountered difficulties, in particular in connecting the various zones of the document. So this first phase of work on Doc2 was an opportunity, for these students, to become aware of, and to express, their difficulties.

However, the students did not prove able to estimate the coherence of the document, and even less to detect the possible implausible and/or facilitating elements used by the designers, probably because of the complexity of the document.

Briefly put, the possible attainments of the students after the first session were probably screened by the complexity of Doc2. In Gunstone's wording, we might say that the broached content was too "unfamiliar" in this case.

Third session

School-oriented reduction with Doc3

After the two first sessions of the TLS3 sequence, an individual homework activity was given to students, concerning a third document (Doc3). With the same method as for the two other documents, we analysed the students' comprehension of the main message. For the sake of brevity, we simply mention in Table 7 some results that can be directly compared to those mentioned in Tables 2 and 5. Table 7 displays the number of students who reformulated the main message in conformity with our reference, and of students who kept to a school-reduced position throughout their responses about this document. In this case, a school-reduced approach consists in exclusively focussing on the structure of matter, a topic on the current syllabus.

Table 7. Impact of school-oriented reduction in students' responses about Doc3.

(N_T=94) Category of response	Doc3 Number of students
Reformulation of the main message: conforms to our reference	70
Exclusive focus on matter	14

It must be noted that, in contrast to what was observed with the two first questionnaires (Q1A, Q2A), a noticeable number of students (43/94) showed a school-reduced interpretation at the beginning of their responses, then were able to provide an appropriate interpretation of the main message in their subsequent responses. In other words, the main message was not screened by their first school-oriented reading.

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Discussion of the results concerning the main message and the FEPOs

The preceding results show some improvements in the students' attainments between the first session and the third one. Given what is observed for Doc2, it can be suspected that the type of document strongly influences the results. Therefore a mere comparison of rates of answers before and after teaching cannot suffice to evaluate the impact of this teaching-learning sequence. Even with one given document, say Doc1, a comparison of responses before and right after teaching might show the result of rote-learning, rather than of new critical stance.

This said, these results seem compatible with our initial expectations concerning students' tendency towards school-reduced reading. They also confirm students' difficulty to comparatively evaluate the possible consequences of FEPOs as concerns reader comprehension.

Also compatible with these findings is the idea that, the more difficult it is to understand a document, the more likely that a school-oriented reduction will be observed in the students' comprehension of the document. We can also make a new assumption, concerning students: The more difficult it is to understand a document, the less easy it is to identify the FEPOs and to organise them in a hierarchy.

In this context, the role played by the discussions with the teacher appears crucial. Thus, the first discussion was decisive, each year, to get the main message of Doc1 properly expressed in a collective context. Even if this does not mean a general agreement and appropriation by the students, this achievement served as a basis for the second discussion of the same document, about the FEPOs. Again, what we observe in students' individual responses at the end of the corresponding session is not necessarily a stabilised competence in this domain. But the students have experienced a new kind of work, taking some distance with the mere contemplation of beautiful images and with a school-reduced approach of the document. The outcome of the third session is compatible with this positive evaluation of the students' progress.

At the same time, students might have considered that the corresponding effort was not worth it. Here, another component of the students' reactions to this TLS3 sequence can complement our understanding of its actual impact. More specifically, we need to better understand what might induce students to make the required effort to overcome a school-reduced reading.

Motivating Surface Features Vs Students' Intellectual Satisfaction

Consistently with our hypothesis of a virtuous circle involving the comprehension of the main message, the comparative evaluation of FEPOs, and students' intellectual satisfaction, we thought it worthwhile to pinpoint students' comments relating to the engaging aspect of a PUS-document.

General comments in answer to questionnaire 1A (Doc1)

As said above, 63% of the pupils (59/94, Table 3) formulated general remarks or criticism about Doc1. With this relatively important sample, we were able to detect some signs of satisfaction or dissatisfaction. We wished to pinpoint the reasons of their possible satisfaction and to better understand whether the engaging aspect of a document was sufficient from this standpoint.

We classified the students' remarks in 6 categories (de facto exclusive):

- Comment that gives a rather positive impression of the document; still global
- Comment that gives a rather negative general impression of the document; still global
- Comment that highlights funny or engaging parts of the document
- Comment specifying that the document is easier to understand than a scientific text or a textbook

- Mixed comment, e. g.: "It is indeed (positive comment)… But (often followed by the mention of a FEPO)"
- Other

The results displayed in Table 8 concern the 59 pupils who formulated general criticism or comments.

Table 8. General criticism or comments with Quest. 1A. (years 1, 2, 3), (de facto: exclusive categories).

Comments	Occurrences (N=59)
Rather positive general impression of the document.	18
Rather negative general impression of the document	11
Emphasis on funny or engaging parts of the document	11
The document is easier to understand than a scientific text	3
« It is indeed (*general comment)…* But … *(often, FEPO)* »	9
Other	7

We note that about half of the concerned students (30/59, lines 1, 4 and 5) expressed a positive judgment, with sometimes (N=14: lines 4 and 5) some specified reasons.

"This document is good because it is simple to understand, because the drawing is well done and rather explanatory and the text is short with simple words".

"I think that this document is good because it provides us with plenty of illustrated explanations".

But only 3 students mention that, according to them, the document facilitates comprehension:

"This document is good because it shows us a pleasant way to understand some ideas".

Moreover, about a third of these (20/59, lines 3 and 6) clearly expressed some reservations. Among them, 9 (line 6) clearly questioned the document's contribution to comprehension.

"The document is rather implicit and difficult to understand."

"Somebody who has not studied the phenomenon before cannot understand what the image is intended to show all by himself."

It would then be oversimplifying to claim that a colourful image and an amusing context are sufficient to entail students' satisfaction.

The third part of the discussion in class: student satisfaction

The last part of the discussion with students about each document, in particular Doc1, confirms that their views were more nuanced.

To start this discussion, the students were asked whether they felt interested and motivated by Doc1. Our goal was to look into whether the pupils considered that a "hooking" effect facilitated their understanding of the document, and to what extent their reflection about this point could become more mature.

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Box 3. Excerpts of the guided discussion about satisfaction and comprehension in Doc1. Bold fonts indicate students' responses (previously selected); italics in the column on the left designate students' interventions.

Transcript	Our comments
Student A: – Well, I agree with response 1.	
Teacher: Response 1): **"It's a good idea to have done that: the drawing is funny, it's a little more playful than a schoolbook".**	
B – Yes, but finally, there are fewer things than in a schoolbook.	*The student spontaneously points to the difference between this document and what can be found in a schoolbook.*
C – Yes, but we aren't obliged to understand everything at once.	
T – What do you mean? We can move on to response 4): **« Somebody who has not studied the phenomenon before cannot understand the phenomenon by himself»**. What do you think of that?	*The teacher orientates the debate towards the understanding of the main message.*
D – Well, that it's true.	*The student seems critical about the document.*
All – Yes, it's true.	*Collective approval*
T – All right, now, response 7: **"Not very realistic, but we can understand a comic strip more easily than a scientific text".** What do you think of that?	*The teacher attempts to introduce the distinction between a hooking effect and an aid to comprehension.*
C – Well, there are simpler words in a comic strip than in a scientific text.	
T - But is it easier to understand with an image than with text alone?	
All – No!	*Rapid collective agreement about this distinction.*
T – … Do you think that it is because it is amusing that we understand better?	
E – No.	

Although the merits of such documents were not denied, the students easily agreed that an engaging effect due to surface features and simple words do not necessarily entail easy comprehension. This observation is compatible with the negative version of the virtuous circle: without comprehension, students' satisfaction remains limited.

Comments about the homework activity (Doc3)

The positive version of the virtuous circle seems to be echoed by the comments of several students, collected in the written work about Doc3.

"I found this work very instructive, it enabled me to study a document in depth and to write a critique of a popularisation text. I think that a document of this type should contain simple but clear explanations. When some notions are simplified too much, they sometimes end up being barely understandable. (...) Doing this work, I also realised that the goal of physics was to extract relevant pieces of information from a document and to select the main ones, and not just to make calculations or experiments."

"I found this work rather difficult because building criticism upon arguments takes thought. It gave me an opportunity to innovate by approaching this subject in a literary way, and I spent several hours on this."

"In the first place, this work helped me to develop my critical sense. Now, I understand better why it is necessary to consult several sources to be sure about the pieces of information that we talked about. So it is interesting to analyse a document, and to know exactly what we understand and what we do not understand".

"This work convinced me that it is necessary to take time to read an article, and not just glance through it, because it may be very interesting. We should not give up because of something we do not understand. It also made me understand that I could be interested in a subject which, at first sight, would not have attracted me if I had not been obliged to work on it (...) After all, this work made me much more aware of things I would not have thought of otherwise."

Although we do not often find all the components of the virtuous circle explicitly mentioned in a given comment, we commonly find several of them, or affiliated ideas, such as effort, coupled in the argument: thorough analysis, critical stance and comprehension in the first comment cited above, critical stance and a long time willingly devoted to the work in the second, critical stance, comprehension and interest in the third, and time spent, interest, attractiveness and learning in the fourth.

Such comments are far from exceptional, and may be seen as direct confirmations that our hypothesis of a virtuous circle is relevant, at least for a non-negligible number of students.

The Complete Sequence: Assessment of Satisfaction

This assessment of satisfaction concerned the pupils who took part in the critical activities on PUS-docs that we have just presented. Over the three years of the experimentation, 87 pupils answered at the end of their school year. The analysis of this assessment aimed to document two questions:

– How was the critical work on PUS-docs perceived by the pupils in comparison with other activities carried out during the year? – Is there a notable difference in this respect between the students who intend to pursue scientific studies (identified as "S") and the others (identified as "Non S")?

The questionnaire included many questions concerning various types of activities proposed to the students during their school year. Students were asked to rate the interest and usefulness of each type of activity, on a scale of 1 to 5 (1: uninteresting… 5: fascinating).

Figures 3 to 6 outline the main results, concerning the work on PUS-docs, the classical exercises and the experimental activities. They display the percentage of pupils having answered 4 or 5 concerning "the interest" or "the usefulness" of each of these types of work, carried out in class (figure 3 and 4) or at home (figure 5 and 6).

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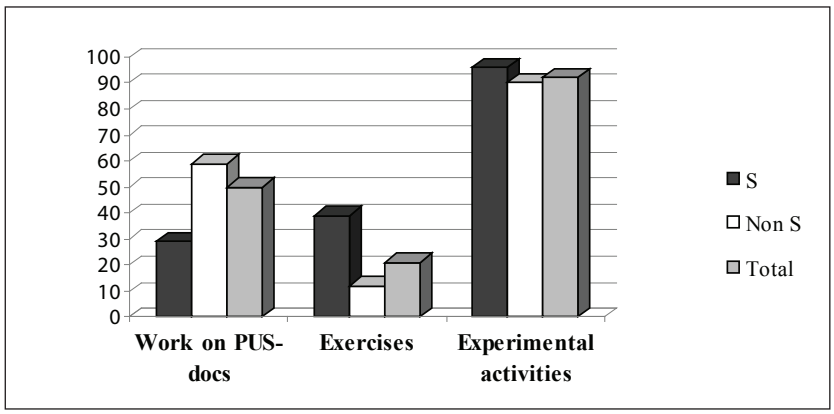

Figure 3. Percentage of satisfaction (rating 4 or 5 on a scale of 1 to 5) as to the interest of the various activities in class with S/Non S distinction.

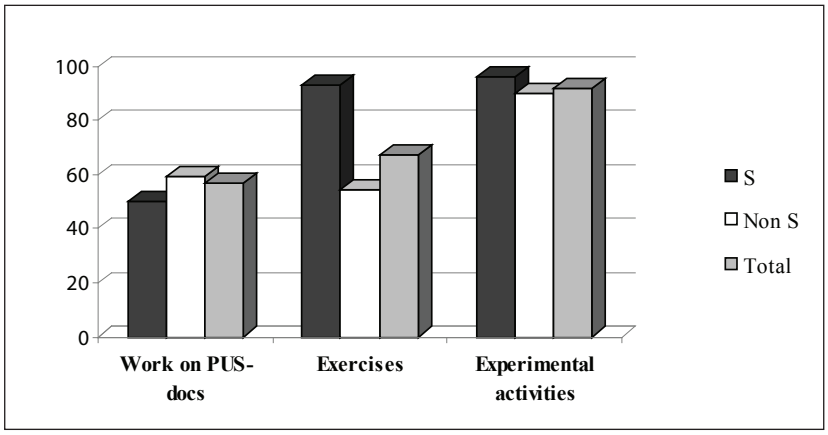

Figure 4. Percentage of satisfaction (rating 4 or 5 on a scale of 1 to 5) as to the usefulness of the various activities in class with S/Non S distinction.

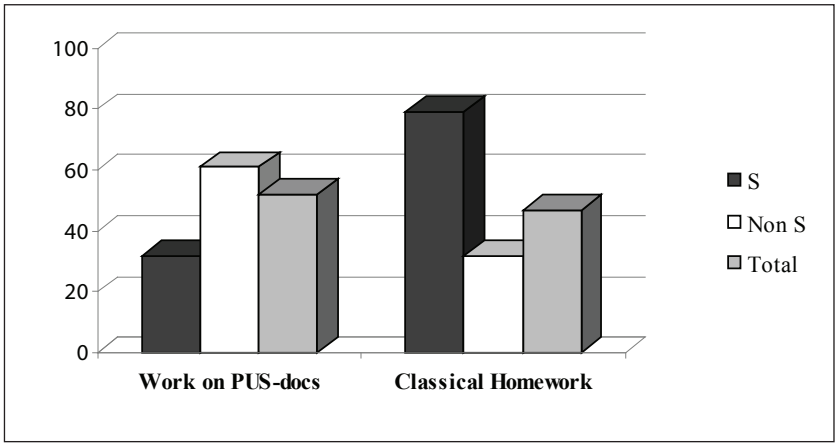

Figure 5. Percentage of satisfaction (rating 4 or 5 on a scale of 1 to 5) as to the interest of the various activities carried out at home, with S/Non S distinction.

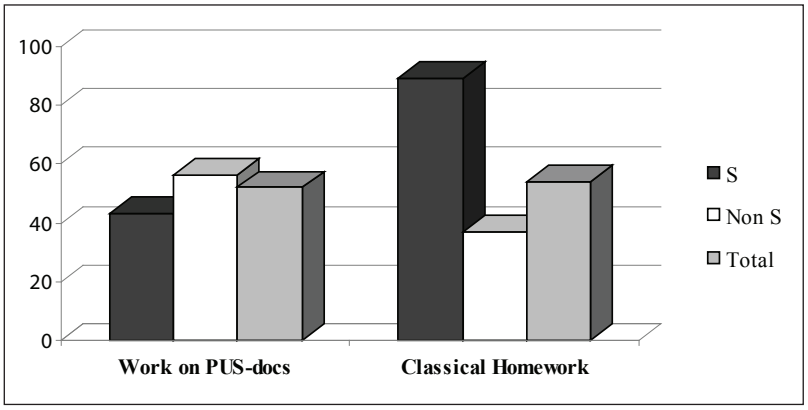

Figure 6. Percentage of satisfaction (rating 4 or 5 on a scale of 1 to 5) as to the usefulness of the various homemade activities with S/Non S distinction.

The results displayed in Figure 3 concern the work in class. They show that the critical work on PUS-docs is clearly appreciated by half of the students. Considering the whole sample, the results suggest that students consider this type of work as less interesting than the experimental activities but more interesting than exercises. One also notes a considerable difference between the rating of the future scientific pupils ("S") and that of the others ("Non S"): The future scientific pupils are more interested in exercises than in critical work on PUS-docs, whereas it is the reverse for "Non S" students. The χ^2 tests in this respect attest to a very significant difference ($\chi^2 = 18.1$, $p<0.01$).

Concerning the usefulness of these activities (fig. 4), the results for the whole sample suggest that critical work and the exercises are broadly equivalent. However, the "S"/"Non S" disparity is confirmed. The future scientific pupils who enjoy the critical analysis of PUS-docs are far fewer than those who enjoy the exercises, whereas the pupils who do not intend to pursue scientific studies rate these two types of activity as having broadly the same level of usefulness.

The results concerning the work carried out at home (fig. 5 and 6) are broadly similar to the previous ones. As regards interest, critical work requiring analysis and classical homework – that is, a succession of training exercises – seem to be equally rated by the whole group. But again, the "S"/"Non S" disparity is striking. The future scientific students ("S") who were interested in the classical homework were more numerous than those interested in the critical analysis of PUS-docs, whereas the proportion is reversed for the other students ("Non S").

Figure 6 displays the students' ratings concerning the usefulness of the two types of homework. The results are not very different from those concerning their interest in the two activities concerned: the "non S" interested in the critical analysis of PUS-docs were more numerous than those interested in classical homework, and the tendency is clearly reversed for the "S".

To sum up, two main features emerge from this assessment of satisfaction. On the one hand, considering the whole sample, the interest and usefulness of the activities organized in the framework of the TLS3 sequence were considered satisfactory by a good half of the students. Note that this was not the case when students rated the interest of exercises carried out in class. On the other hand, we observe an important disparity in the students' ratings of the interest and the usefulness of this work according to their intentions for their future studies. It seems as if the future scientists were in search of performance, and therefore considered the critical analysis of documents as less useful and less interesting than more traditional activities. As for the students who do not intend to pursue scientific studies, they appear to feel the need for another approach towards science, and the analytical work of the TLS3 sequence seems to have satisfied them in that respect.

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Concluding Remarks

In view of this classroom-based experimentation, we suggest that several components of the results deserve attention.

In terms of collected data, the stability of the findings over three years is worth noting. The students' commitment to the proposed tasks, itself very stable, might be linked to a particular teacher (the first author of this paper), but not to a particular group of students. This result contributes to our judgment concerning the realistic character of this sequence, although the critical work was very unusual for the students. This would not necessarily have been the case with a different set of documents. We can only say that, with those that we selected, the type of work that we designed was manageable by this teacher, willingly accepted by the three different groups of students, and informative given the stability of the observed attainments.

Among the expectations that we aimed to test in this classroom context, the students' tendency to read popularisation papers with a school-reduced approach was actually observed. This consists in reading such a document with an exclusive focus on concepts of the current syllabus at the expense of a more global understanding. Suggested by a preliminary investigation, this expectation was amply confirmed by several observations. Thus, the first reading of each of the three documents we used entailed a notable rate of school-reduced interpretations. The main message was properly expressed by numbers of students which increased as the numbers of school-reduced readings grew smaller. This kind of anti-correlation may be seen as intrinsic to our definition of a school-reducedreading, but it might also mean that this school-oriented approach constitutes a refuge, when a document seems too complex. Thus, the corresponding scores might be partly linked to the extent of difficulty presented by each document. This interpretation seems reasonable, concerning the second document, according to our estimation of its conceptual and structural complexity. A factor likely to positively influence the students' achievements – in terms of school-reduced reading – is the teaching-learning process during the TLS3 sequence, in particular the value of the guided discussions. Indeed, it was in the third session that students appeared the least blocked by a school-oriented approach.

The second expectation concerned the students' ability to detect and evaluate the implausible, and / or facilitating elements (FE) that the author of a document brings to bear in order to catch the reader's attention, at the risk of introducing a potential obstacle (PO) to comprehension. We thought, on the basis of the preliminary investigation, that such FEPOs would be at best detected but rarely organised in a hierarchy. That is, we expected that students would not frequently designate one FEPO as being, *a priori*, more consequential than another. The first of the analysed documents proved particularly appropriate to test this assumption, because many FEs were detected by the students. Moreover, among these implausible elements, the best candidate to hinder the reader's comprehension was easily agreed upon among the authors. Indeed, the size of the Earth was greatly exaggerated, on a document that aimed at suggesting a distance of a few hundred thousand light years between this planet and its observers. Out of the few students who detected this FEPO, none suggested that it was, potentially, more consequential for the reader's comprehension than, for instance, the presence of two ETs – the observers – speaking French on a small colored planet. After the session concerning this document, a third of the students were able to appropriate this type of analysis. This low – but stable – rate can be seen as a partial success. In any case, it confirms that the targeted ranking is far from natural for the students. Nevertheless, the transcripts of the guided discussions offer a somewhat different view. Repeatedly, some lively exchanges between students and teacher were observed, and the group rather quickly proceeded towards a consensus in this respect.

Probably, the most convincing outcomes of this investigation are not so much the students' quantified achievements as their comments. The design of our sequence was founded on the assumption that a critical analysis of the document contributes to a better global understanding of the main message, and vice versa. It was also assumed that one of the elements that were relevant in this synergy was the students' intellectual satisfaction. On this ground, we collected

symptomatic comments that explicitly associate an exigent analysis, the thorough consideration of the broached content, the time devoted to this work, and a degree of final satisfaction. These comments are not compatible with the view that students at this level would, intrinsically, be reluctant to take part in such unusual intellectual activities.

On the other hand, the accompaniment that they benefited from, even with a short teaching time (slightly more than 4 hours in all), seems decisive as regards their evolution. This work, with its meta-cognitive component, enabled a noticeable number of students to evolve from a motivation based on the surface features of the considered document to an authentic intellectual satisfaction. Also worth noting is the difference that we observed, in our sample, between students intending to specialise in science and those who did not. The fact that the latter were more in favour of the type of work analysed in this paper deserves, we think, further attention.

We are, however, aware that validating the hypothesis of the "virtuous circle" is problematic. This is due to the systemic character of this hypothetical network of relationships. Assuming multiple and reciprocal relationships between parameters comes down to acknowledging that they are not separable. In particular, intellectual satisfaction cannot easily be quantified. In this study, the students' – sometimes very explicit – comments constitute the most convincing clues in this respect. We could summarize an essential limit of our investigation by stating that the "virtuous circle" is rather "illustrated" than "validated". Despite this type of difficulty, we suggest that emotional parameters such as "motivation", often exclusively envisaged as possible *conditions* for better learning (e. g. Laukenmann *et al*., 2003), could be also profitably researched as possible *products* of a teaching-learning process, as achieved through the TLS3 sequence.

The fact that the teacher was also a researcher can be seen as another limitation to this study, as argued for instance by Leach and Scott (2000). Our investigation is a first step, and documents what happens when a teacher transforms the didactic intentions of the TLS3 sequence as little as possible, to borrow a formulation used in the STTIS project (1997–2000). How ordinary teachers may appropriate and/or transform this sequence is a different and crucial question, to be researched as such. In order to extend the use of such sequences, in particular to check the stability of our results, a challenge is to be faced; that of analysing more precisely than we did what factors might, *a priori*, determine students' perplexity when reading a popularisation document. A conceptual and iconic analysis – beyond the mere account of the number of zones in the document – is a non-trivial task, particularly if conceptual complexity is added upon structural complexity.

The interest of designing working techniques for the classroom use of non-scholastic documents has been reinforced by a recent phenomenon. A flowering of pseudo-documents of non-scholastic origin has been observed in recent textbooks, in particular in France (Feller 2008). Numerous "Documentary Activities" are proposed at the end of chapters, intended as incentives to enlarge students' scientific culture. In fact, such documents are generally presented with strictly scholarly questions. On this ground, further studies, both about teachers' practices and students' reactions, would be relevant.

We suggest that it might be useful, in such studies, to bring to bear the ideas of a school-oriented reduction and of a hierarchical organization of implausible and / or facilitating elements, also seen as potential obstacles to comprehension. Their use beyond a school context – *strictly speaking* – might also be of interest, in the perspective of bridging the gap between education to the media and ordinary teaching.

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