



## Light pollution in natural science textbooks in Spanish secondary education

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### Abstract

Light pollution has emerged with the industrial development in recent decades. It is becoming a significant environmental issue for cities today and it will probably become more important in the near future. However, very little research has been carried out on this issue in the field of science teaching, despite there being a general agreement that education has an important contribution to make in the protection of the environment. This research analyses this problem in secondary education, through the official curriculum and textbooks published for the Valencian Region (Spain). We have based the research on the "Content analysis" method. Light pollution, despite being included in the Spanish compulsory secondary education curriculum, is an issue that is barely touched on in the majority of the first and second year Natural Science textbooks analysed.

**Keywords:** Light pollution, Secondary education, Natural science textbooks, Spanish secondary education curriculum.

### Introduction: problem statement

New kinds of pollution have emerged through industrial development, as is the case of light pollution. Calvo (2010) defines it as "The glare caused by artificial light that is lost and escapes to the sky, originating mainly from inefficient lighting, which then illuminates suspended air particles and forms an immense dome of light projected at the night sky, subsequently eliminating the night's natural darkness".

This type of pollution is increasingly significant, despite the fact that it receives less attention than it warrants from the science teaching perspective. In science education, when pollution-related issues are addressed, mention must also be made of other types of pollution that are often forgotten but are just as harmful, such as light pollution (Edwards, Gil, Vilches & Praia, 2004).

The importance of this issue has been addressed in documents and proposals such as the universal declaration of the rights of future generations, pointing out that "persons belonging to future generations have the right to an uncontaminated and undamaged Earth, including pure skies" (UNESCO-Cousteau Team, 1994).

Despite the increase of political, legislative and technical initiatives to reduce the problem of Light Pollution, data indicate that the problem is far from solved. Widespread citizen participation is required if the situation is to be turned around. Solutions must arise from social demands, and for this to happen, the first step is for participants to be informed. As indicated by Punter (2010), "Classrooms are a true reflection of the changes taking place in society and how these changes

generate among citizens concerns, wishes, confrontations or on the contrary passiveness”.

Environmental education plays a key role in raising citizens' awareness so that they demand changes that contribute to sustainable development. Environmental education is essential for achieving sustainable development, therefore it is most important that besides informing society, values are developed and possible solutions or alternatives are planned. As Campbell, Waliczek and Zajicek (1999) indicate, students having higher knowledge had more favorable environmental attitudes compared with students with lower knowledge.

In the nineties, Cinzano and Di Sora (1993) of the *Società Astronomica Italiana* and the *Unione Astrofili Italiani* had already reported that the lack of awareness in Italy was the biggest problem in creating a movement of opinion in favour of lighting control. That's the reason why, education was the main thrust at all levels. But even today, a recent paper confirms the importance of population in understanding light pollution (Olsen *et al.*, 2014).

Probably lack of knowledge and awareness is the main problem facing the light pollution in most countries with this problem. It is this sense education has much to say.

### **Textbooks in the teaching learning process. Review of relevant literature**

For decades, several authors (Alvermann, 1987; Freeman, 1988; Campanario, 2001; Mazzitelli *et al.*, 2005; among others) have suggested that the textbook is one of the essential materials on which teachers rely for the development of their professional activity and to which they assign the greatest importance.

The interest in analysing textbooks is due to the fact that in practice, teaching is not so determined by decrees and ministerial orders as by the textbooks used in the classroom. (Schubring, 1987). Despite some teachers using other alternative methods, such as project work and others, these are in the minority and the school book is still one of the predominant teaching tool in the education system. For all of the above, the analysis of textbooks is important in that they provide information on the issues addressed in the classroom.

Despite being a significant issue, the problem of light pollution has hardly been addressed in research in science teaching in formal education. Amongst the brief Spanish literature that exists, we must highlight the paper written by Zuza & Alduncin (2009) related to teaching proposals for studying this issue in the classroom.

At the international level, in recent years have published several studies related to light pollution but from other points of view that are not educational, for example, the perception of light pollution in Hong Kong (Chui, 2008) or Finland (Lyytimäki, 2013), studies for limiting the impact of light pollution on human health, environment and stellar visibility (Falchi *et al.*, 2011), the effects of light pollution on ecosystem and countermeasures (Jian, 2007) or even focusing on society's disregard for the loss of a cultural asset that has been a part of art, science, and culture for as long as these things have existed (Galloway, 2010).

On the other hand, Percy (2001) has worked light pollution with students, teachers and general public, both formal and informal education. As he says, in many countries, astronomy is part of the school science curriculum; it is part of the US National Science Education Standards and the Canadian equivalent. However, light pollution may not be an explicit “topic” in science curriculum.

Also dealing with light pollution and education, a remarkable initiative was carried out by Crawford, Metaxa and Percy (1998) who directed a light pollution project in Greece called *the Universe in your Classroom*.

Therefore the study of how light pollution is handled in secondary education is of prime interest

mainly due to its newness. For this reason we have analysed how this issue is addressed in the official curriculum and in Natural Science textbooks in Secondary Education in the Spanish education system, focusing on the first cycle, that is first and second years, attended by young people aged between 12 and 14 years old.

### Approach to the problem and research methodology

We have already mentioned the scarce amount of publications that exist on issues related to light pollution within research on science teaching, and that besides, light pollution is an ever increasing problem in cities. In this paper we ask if this type of pollution has been included in the secondary education curriculum, and if it is included, how it is dealt with in textbooks.

We set out from the hypothesis that in Natural Science textbooks in Spanish secondary education, light pollution is not addressed in an appropriate manner, since the competences established on the curricular level are not addressed, as not all teaching ambits are included (conceptual, procedural and attitudinal) and the importance this issue really warrants is not actually assigned to it. In order to verify the hypothesis we explored if the curriculum includes the competences by means of this issue and if so, to what extent do textbooks include them.

So the research was focused on achieving the following objectives:

- To analyse the first and second year curriculum of secondary education to ascertain in which subjects and years light pollution is studied.
- To analyse how Natural Science textbooks at this level address light pollution and if so, determine in which teaching ambits it is included (conceptual, procedural and attitudinal).

#### *Curriculum analysis*

Our work analysed the secondary education study programme in the Valencian Region as this is where the authors perform their professional activity, but the legislation on which we have based the work is similar to that of other regions. Therefore, we understand that the results may be applied throughout the country. This part of the analysis consisted of reading the secondary education curriculum in order to determine if it contains aspects related to light pollution.

#### *Textbook analysis*

The textbook analysis was performed on a sample of fifteen Natural Science textbooks from the first and second years of Compulsory Secondary Education, eight of which corresponded to the first year and seven to the second (table 1). The choice of publishers was made bearing in mind that their textbooks are those most widely used in Spanish secondary schools.

**Table 1.** Publishers

1 <sup>st</sup> year of secondary school	2 <sup>nd</sup> year of secondary school
Grupo Editorial Bruño	Editorial ECIR
Editorial ECIR	Ámbar. Oxford Educació
Grupo Anaya (2009)	Libro 3D. Nuevo Natura. Ediciones Vicens Vives
Adarve. Oxford Educació	Vorammar Santillana. Proyecto La Casa del Saber
Projecte Àmfora. Oxford Educació	SM.
SM.	Grupo Anaya
Marjal-Grup Edebé	Mc Graw-Hill. Projecte Xúquer.
Grupo Anaya (2011)	

We have applied the method of “content analysis”, this enables the presence of certain content in a text to be verified (qualitative assessment), the results of which are subsequently presented qualitatively. Content analysis is based on reading (textual or visual) as a tool for collecting information, a reading that unlike common reading should be performed following the scientific method, that is, it should be systematic, objective, replicable and valid. Content analysis represents a pedagogic instrument of unquestionable interest in the field of experimental science teaching.

One component of content analysis is the conversion of symbols that make up every message in numerical values susceptible to mathematical and statistical treatment. That is, for the analytical treatment of a text, firstly the coding-categorising of the content should be performed. The object of coding is to provide a formalised representation in accordance with a set of rules, a model of the content of the text. In categorisation the different codes resulting from the previous process are classified into categories, depending on the previously established criteria.

With the textbook analysis we will be able to ascertain the proposals made by different publishers for teaching/learning of light pollution, and on the other, compare proposals depending on each publisher. Calvo (2005) and Martínez & Penalva (2007) have developed assessment models for school manuals and research that has addressed the issue of textbook analysis.

#### *Analysis grid and assignment of values*

Table 2 presents the criteria for assigning values depending on how light pollution is addressed in the manuals. It consists of twelve items that allow us, firstly, to determine the presence or absence of this type of pollution, and also to ascertain how light pollution is approached from the different teaching ambits: conceptual, procedural and attitudinal. To prepare this table the analysis grid designed by Martínez & García (2009) was taken as a reference and adapted to our purposes.

Depending on the presence of each one of the items in the texts, a value of 1 was assigned if it appeared and 0 if it didn't. In the cases where an item is only partially complied with, 0,5 is assigned. Each ambit (concepts, activities/procedures and attitudes/values) was assessed according to the percentage of compliance with items (1 to 5: concepts; 6 to 9: procedure; 10 to 12: attitudes). It was considered that light pollution was addressed properly when publishers addressed the issue in over 25% of the three teaching ambits.

**Table 2.** Criteria for textbook scores

Concepts	
1. How many times is light pollution mentioned?	For the assessment of this item the textbook that most often mentions light pollution was used as a reference (9 times) and was assigned the maximum rating (1).
2. Is light pollution defined?	This item addresses the issue of if a definition is provided of the meaning of "light pollution".
3. Are the risks linked to light pollution mentioned?	This aims to determine if the risks that this issue implies are included: difficulty for astronomy observations, effects on biodiversity, disappearance of natural darkness at night, changes in people's health, excessive use of electricity and risk of accidents.
4. Is energy consumption in lighting addressed?	This item aims to determine if in textbooks discriminations are made between the percentages of energy used for different purposes: heating, domestic appliances, etc. Specifically, in the percentage of energy used in lighting, both of a domestic or public nature.
5. Is any reference made to the link between light pollution and other environmental problems?	By means of this item the aim is to analyse if light pollution is linked to other problems, such as for example global warming, loss of biodiversity, etc.
Activities/Procedures	
6. Is research encouraged on the problems linked to light pollution?	The objective is to ascertain if research activities are proposed in which students are required to look for information on websites, books, written media, etc. Differentiating between reliable and unreliable information sources.
7. Are activities encouraged that require the use of argumentation?	This item assesses if the activities proposed to students encourage the use of argumentation, that is, if students justify their responses based on evidence and sound reasoning.
8. Are laboratory activities encouraged?	This item assesses the existence of laboratory activities linked to light pollution.
9. Are field activities encouraged?	This item aims to assess if field activities are proposed linked to light pollution.
Attitudes/Values	
10. Are students encouraged to give careful thought to the importance of the light pollution problem?	This item rates if the books' content, activities, etc. promote careful thought and consideration by students on the importance of the light pollution problem.
11. Are proposals and implementation of corrective measures regarding light pollution promoted?	This analyses the existence of proposals for light pollution corrective measures and the application of these measures in students' daily life.
12. Are students encouraged to implement energy saving methods on a day to day basis?	This aims to determine if information is given on possible energy saving measures in students' day to day life or if the students themselves encourage the proposal of energy saving measures.

## Results

### *Curriculum analysis*

Table 3 presents a chart showing the contents related to light pollution included in the subject curriculum of Natural Science in the first and second years of secondary education in the current legislation (Decree 112/2007 of the Generalitat Valenciana).

**Table 3.** Light pollution in the first year natural science curriculum

	CONTENT
<b>First year</b>	
Block 2. The Earth in the Universe	The Universe and the Solar System. - Observing the Universe: planets, stars and galaxies. - Use of orientation techniques. Day and night sky observation.
Block 3. The Earth's matter	- The atmosphere. Atmospheric contaminants: nature, sources and dispersion. Relationship between air and health.
Block 4. Living things and their diversity	- Classification of living things. Assessment of the importance of maintaining the diversity of living things. Analysis of the problems linked to their loss. Biodiversity in the Valencia Autonomous Region. Current situation and perspectives.
<b>Second year</b>	
Block 2. Matter and energy	Energy in material systems. - Problems linked to obtaining, transporting and use of energy. - Raising awareness of the importance of energy saving.
Block 3. Energy transfer	Light and sound. - Light and sound as wave models. - Light and vision: objects as secondary light sources. - Rectilinear propagation of light in all directions. Recognition of situations and performance of simple experiments to prove it. Shadows and eclipses. - Qualitative study of reflection and refraction. Use of mirrors and lenses. - Decomposition of light: colour interpretation. - Sound and hearing. Propagation and reflection of sound. - Assessment of the problems of noise and light pollution.
Block 6. The natural environment.	Influence of biotic and abiotic factors on ecosystems

As seen in table 3, the concept of light pollution only appears explicitly in the second year of the subject of Natural Science, specifically in the block of curricular content number 3, titled "Energy transfer", in which the need to assess the problem of light pollution is established.

However, also in the curriculum there are other contents related to the issue under study, such as those included in the above mentioned table. Said contents are susceptible to including certain aspects of the issue that appear in other blocks of curricular content both in the first and second years.

In addition to the explicit references that appear in table 3 above, legislation establishes among the objectives that "compulsory secondary education will contribute to developing in students the capabilities that enable them to critically appraise social habits related to health, responsible consumption, the care of living beings and the environment, by contributing to its conservation and improvement".

#### *Textbook analysis*

For reporting the data obtained a double entry table was used in order to compare quantitative data among publishers and thus reach conclusions. To preserve confidentiality we have left out the names of publishers from the results and conclusions.

By applying the items mentioned in the analysis grid (table 2) and assigning the value corresponding to the different textbooks, we have obtained the results that appear in table 4.

Table 4. Results of publisher scores

	First year							Second year							
Publisher	11	12	13	14	15	16	17	18	21	22	23	24	25	26	27
CONCEPTS															
Item 1	0	0	1	0,5	0	0,5	0	0	0	0	1	0,5	1	1	0
Item 2	0	0	1	1	0	1	0	0	0	0	1	1	1	1	0
Item 3	0	0	0	0,5	0	0,5	0	0	0	0	0,5	0,5	1	1	0
Item 4	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Item 5	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Total	0	0	2	2	0	2	0	0	0	1	3,5	2	4	4	0
%	0	0	40	40	0	40	0	0	0	20	70	40	80	80	0
ACTIVITIES / PROCEDURES															
Item 6	0	0	1	0	0	0	0	0	0	0	0	0,5	0	0	0
Item 7	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0
Item 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Item 9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Total	0	0	2	1		0	0	0	0	1	0	1,5	0	0	0
%	0	0	50	25		0	0	0	0	25	0	38	0	0	0
ATTITUDES AND VALUES															
Item 10	0	0	1	1	0	0,5	0	0	0	0	1	1	1	1	0
Item 11	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0
Item 12	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
Total	0	0	2	1	0	0,5	0	0	1	1	3	3	2	2	1
%	0	0	67	33	0	17	0	0	33	33	100	100	67	67	33

Their analysis leads us to the following results shown below, classified according to the different teaching ambits studied (conceptual, procedural and attitudinal).

#### *Concepts*

Of the 15 textbooks analysed, only 7 mentioned light pollution, in the first year it was mentioned in 3 of the 8 textbooks analysed and in the second year, in 4 of the 7 books analysed.

All the textbooks that mention light pollution (item 1) include a definition of the issue; that is in 7 of the 15 books.

Almost all the books that mention light pollution at least explain some of the risks it entails. In a first year textbook where no such explanation is given; a research activity is proposed in which the students themselves must search the web and consult literature references about the problems that can be caused by light pollution.

Two publishers mention a greater number of risks related to light pollution. However, the other publishers studied only highlight the disappearance of the night's natural darkness, the difficulty incurred in observing the stars and in some cases, excessive consumption of electricity as risks of light pollution.

Only two second year books reflect the percentage of electrical power used for lighting. Another two second year textbooks link light pollution to other environmental problems.

*Activities/Procedures*

In one first year book and another second year book research is encouraged on the problems related to light pollution, one of them underlines the need for finding information from reliable sources and the importance of providing references, whereas the other keeps to proposing the research. For this reason the first publisher has been given a score of 1 point and the second one 0,5 points.

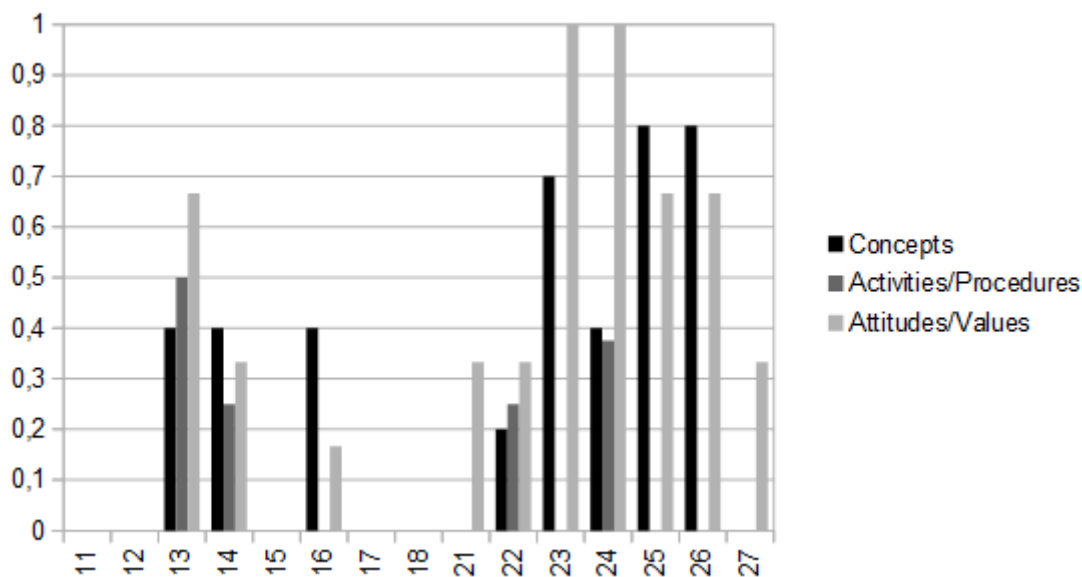
Three of the fifteen books studied include issues about light pollution where students should justify their responses (argumentation), two from the first year and one from the second year. None of the textbooks analysed propose the performance of laboratory activities in relation to light pollution.

Only one second year textbook proposes a field activity that could be related to light pollution. In the issue of ecology it is proposed that the study of an ecosystem be conducted. Amongst the abiotic factors studied, light is included. The use of a photometer is recommended for measuring light intensity.

*Attitudes/Values*

Seven (3 from the first year and 4 from the second year) of the fifteen textbooks analysed encouraged giving careful thought to the importance of the issue of light pollution. A first year book was awarded 0,5 points, since despite including light pollution as another example of pollution within the theme of the atmosphere, no activities are proposed for helping students to reflect on the importance of this environmental problem.

Of the textbooks analysed, two (first and second year) encourage the proposal of corrective measures for light pollution and the application of these measures in day- to-day student activity. All the textbooks analysed that belong to the second year course encourage the implementation of power-saving measures in students' daily lives.



**Figure 1.** Analysis of the different publishers

*Analysis by Publishers*

Graph 1 summarises the results by publishers, to which a number has been assigned to preserve anonymity, the first figure refers to the course, so from 11 to 18 they are first year students and from 21 to 27 second year students.



We observed that two textbooks from the first year (13 and 14) and a further two textbooks from the second year (22 and 24) addressed all three teaching ambits.

The ambit best addressed in textbooks is that of attitudes and values, followed to a lesser extent by concepts. However, activities/procedures are addressed to a lesser extent by textbooks.

The ambit of concepts is addressed to a greater extent by second year textbooks from publishers 23, 25 and 26.

The textbook corresponding to the first year course from publisher 13 stands out for its approach to the ambits of activities and procedures.

Finally textbooks from publishers 23 and 24 are those who work best on attitudes and values.

Table 5 shows a summary of the number of books that comply with each one of the percentages by teaching ambit.

Table 5. Percentages of teaching areas

	None 0%	Poor 1-24%	Average 25-49%	Fair 50-100%
Concepts	7	1	4	3
Activities/ Procedures	11	0	3	1
Attitudes and Values	5	1	4	5

As has been explained earlier, we have considered that light pollution has been addressed conveniently in the cases where the publishers address the three teaching ambits in a percentage of over 25%.

Out of the set of seven textbooks addressing the issue, 57% (four) do so from the three teaching ambits mentioned (concepts, procedure, attitudes). Of these four books, three address it appropriately, according to the criteria established of a percentage of over 25% in each of the teaching ambits, two are from the first year (publishers number 13 and 16) and another from the second year (publisher 24).

## Conclusions and Discussion

After analysing the results we are able to conclude that our initial hypothesis has been validated: "In compulsory secondary education light pollution is not addressed appropriately and is not afforded the importance it actually has".

From the analysis of the secondary education curriculum we are able to conclude that despite the fact that the concept of light pollution only appears explicitly in the subject of Natural Science in the second year, other curricular content which is closely related to the issue under study would allow different aspects of light pollution to be developed.

In the analysis conducted, 47% of the total number of textbooks (first and second years) mention light pollution. With regard to second year textbooks, where it is explicitly mentioned in the curriculum, only 57% address the problem.

From the analysis of textbooks we are able to conclude that light pollution is an issue which is dealt with relatively little in the majority of textbooks analysed from the first and second years of Natural Science. Approximately half of the texts ignore dealing with light pollution in the classroom. On the other hand, of the manuals that do address light pollution, only a small proportion does so taking into account all three teaching ambits (concepts, procedures and attitudes).

Furthermore, since the activity-procedure ambit is that least addressed by textbooks, it can be deduced that manuals are focused more on transmitting content rather than elaborating the content itself.

Despite an increase in policy, legislative and technical initiatives for reducing the problem of light pollution, the data suggest that the problem continues to increase. The widest possible citizen participation is necessary for reversing this situation. Solutions must emerge from social demands, and for this to happen the first step is for people to be informed. It is essential that both formal as well as informal environmental education raises society's awareness of light pollution. Besides, in order to address this issue in a suitable manner, it is important that light pollution be included as part of the topics to be developed during teacher training courses.

To end it is worth underlining that this work has focused exclusively on the analysis of textbooks to ascertain which approach to light pollution is used in the classroom, but nevertheless we are aware that the textbook is not only the only tool available to teaching staff in the teaching learning process, therefore it would be both interesting and necessary to complement this analysis with other components of the above mentioned process, a line to be pursued in the research.

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