

Analysis of physics textbooks presenting electromagnetic waves at upper secondary level

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Abstract. Electromagnetic waves represents the propagation of the electromagnetic field. In this study we investigate how electromagnetic waves are presented in physics textbooks at upper secondary level. We focused the analysis on the most used textbooks in Italy and Argentina, as in some other countries the electromagnetic waves are not part of school curricula. We elaborated a rubric according to which we carried out the analysis. Its criteria represents the key aspect that we identified from the epistemological reconstruction. Each criterion is evaluated according to a three-tier scale. The analysis is ongoing, and the results will be presented at the conference.

Introduction and aims

The four Maxwell equations represent a system admitting a wavy solution for the electromagnetic field propagation in space and time. Maxwell already theorized that the variations of the electromagnetic field propagate as a wave [1], but the empirical evidence came later in 1887 from Hertz's experiment [2]. When dealing with electromagnetic waves, students learn that the electric and magnetic fields propagate with a finite speed, and they can also distinguish between the sources of the electromagnetic field and the charge distribution which constitutes the detector system interacting with the propagating field. Furthermore, they can focus on the relationship between the electric and magnetic fields instant by instant in different positions.

The relevance of the propagation of the electromagnetic field also goes beyond the topic itself. Literature shows that some learning difficulties in optics can be related to a lack of understanding of the nature of light as an electromagnetic wave [3]. Thus, within a wider research about learning difficulties related to this topic, we planned to carry out a physics textbooks' analysis aimed at investigating how they present electromagnetic waves. It is a kind of study widespread in the science education research [4], as textbooks represent an indispensable resource for students and teachers. Nevertheless, some physics curricula for secondary school do not involve electromagnetic waves, so we focus the analysis on the main textbooks used in Italy and Argentina.

Theoretical framework

Following a typical framework used to analyse textbooks [5], we elaborated a rubric consisting of 4 basic criteria. They are reported in Table 1, where their meaning is specified according to examples of some specific indicators they refer to. These criteria were derived from the epistemological reconstruction of the classical theory about electromagnetic waves. Following this framework, the specific research questions that guide our study are:

1. How do textbooks explain the relationship between electromagnetic waves and their sources?
2. How do textbooks explain the propagation of electromagnetic waves in vacuum?
3. How do textbooks explain the interaction of electromagnetic waves with matter?
4. How do textbooks explain the applications of electromagnetic waves?

Table 1. Definitions of the criteria used In the analysis.

Criteria	Specific indicators related to the criteria
Sources of electromagnetic waves	The sources of EMW are accelerated charges.

<u>Propagation of electromagnetic waves</u>	The propagation is not instantaneous and it occurs also in vacuum in the form of transverse waves.
<u>Interaction of electromagnetic waves with matter</u>	Making explicit which quantities are changing when changing the medium. Providing an explanation of the subdivision of the electromagnetic spectrum in different regions.
<u>Application of electromagnetic waves</u>	Providing examples of applications and technologies related to electromagnetic waves, also referring to possible dangers arising from exposure to them.

Methods

We carried out the analysis with a sample of 30 textbooks, which represent the most frequently used resources for teaching electromagnetism in Italian and Argentine schools, according to the education ministry databases of both countries. This approach facilitates a comparative evaluation of the pedagogical methodologies adopted in these two nations. We assessed each criterion against a three-tier scale for every book. The scale's levels are delineated as follows:

1. *Appropriate*: the treatment of the theory, law or concept is considered appropriate for the set of indicators.
2. *Mentioned*: some aspects of the criterion are mentioned with comments, but not their explanation is not explicit.
3. *Not mentioned*: it does not mention the problems addressed by the indicators.

Preliminary results and conclusions

The analysis is currently underway, and the findings will be presented at the upcoming conference. Preliminary results reveal that the primary focus across textbooks from both countries is on the propagation of waves. This aspect is generally addressed appropriately in most textbooks. However, the treatment of indicators for other criteria appears to be lacking in completeness across most textbooks. For example, a significant number do not explicitly clarify the necessity of accelerated charges for the propagation of electromagnetic waves, nor do they adequately distinguish the differences in propagation through vacuum compared to matter. Moreover, the topic of applications exhibits the widest range of variability among the textbooks evaluated. The outcomes of this analysis have the potential to pinpoint the origins of certain learning difficulties students face regarding electromagnetic waves. Furthermore, considering that many introductory university curricula share a plethora of learning objectives with the analyzed textbooks, it is conceivable that these findings could be extended to the undergraduate educational context.

References

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