Plasmonics for Dummies: a proposal for teaching fundamentals of plasmonics

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Abstract: We present a video clip collection aimed at assisting first-year undergraduate students in learning the fundamentals of plasmonics. The work includes the design of an educational assessment of the collection's effectiveness in achieving such a goal.

1. Introduction

Current educational trends have prioritized bringing together children and teenagers from Latin America to learn current topics in material science. As a result, this work presents a collection of videographic clips to aid in the learning processes of the fundamentals of plasmonics by first-term undergraduate students in science and engineering programs. Furthermore, we present the design of a future study to assess the actual impact and effectiveness of such a collection.

2. Plasmonics for Dummies

Plasmonics is a subfield of nanophotonics that has recently piqued the interest of the scientific community due to its numerous applications in materials science. It has enabled the advancement of materials characterization techniques such as Raman spectroscopy (SERS), Kerr microscopy, and magneto-optics, as well as applications in biochemical detection, environmental monitoring, and medical treatment, among others. Regardless of the complexity of this field, we have identified that the majority of the basic concepts related to this topic can be taught properly without requiring beginner students to have advanced background knowledge. By revisiting some basic concepts and phenomena of optics, such as light propagation, light waves, electromagnetic waves, refractive index; reflexion and refraction phenomena; dispersion, scattering, and absorption phenomena; evanescent waves, and resonant systems, a qualitative and phenomenological approach to the most relevant features of plasmonics can be reached.

In this regard, our plasmonics research group has recently focused its efforts on the creation of a compilation of video clips titled *Plasmonics for Dummies* which aims to assist beginners in reviewing all of these concepts and phenomena. At the moment, the collection contains four videos: 1. Refractive index and Snell's law, 2. Total internal reflection, 3. Evanescent waves, and 4. Additional titles on collective oscillations and resonance, optical antennas, and other topics are still in the works. The material is accompanied by a manuscript that describes the corresponding topics in great detail. This document was created conceptually and serves as the foundation for writing the script for the videos. The script creates the context, illustrations, background, tone, and details about how to present the ideas properly. Both the manuscript and the script were carefully reviewed prior to the production and editing stages to ensure that they were free of complex or demanding reasoning while still providing a comprehensive treatment. The videos include experimental demonstrations of some phenomena in addition to schematic explanations and friendly presentations of the topics. All of the content, including the video clips, is in Spanish. The complete list of videos can be found by following this link: https://cutt.ly/Pn8ylzS

3. Assessment of the actual impact of the collection: research design

The digital age has had a significant impact on pedagogical and communication activities, affecting teaching and communication processes significantly. As a result of these changes, society is committed to a digital culture that leads to the expansion of knowledge without borders and more with the current COVID-19 context. One of the challenges that this changes project faces is the rethinking of teaching functions, which creates the need to change traditional classroom methodologies and, on occasion, the use of various pedagogical support tools. As a result, it is critical to assess the impact and scope of the material that assists educators in guiding learning processes and encouraging knowledge construction.

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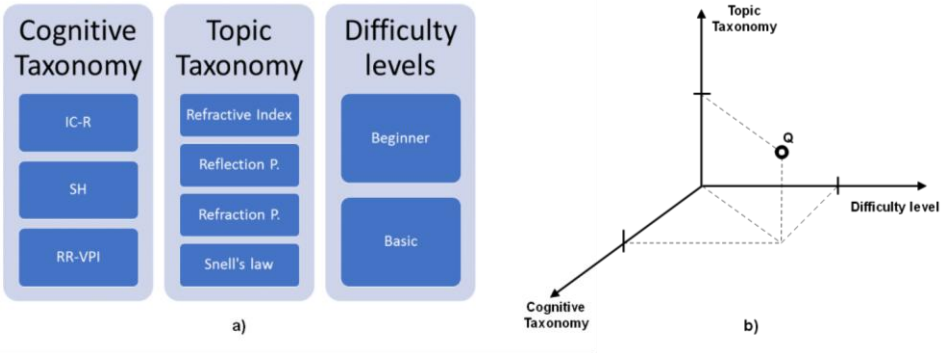
In professional training, evaluation should be viewed as a process of gathering evidence and making judgments about the extent and nature of learning processes, rather than as a comparison between individuals. In rote learning, new information is accumulated in memory without being linked to old knowledge through meaning. This type of learning differs from meaningful learning not only because it does not help to expand real knowledge, but also because new information is more volatile and easy to forget due to a lack of recognition of the links between concepts. According to David Ausubel's theory [4], new knowledge fits into old knowledge, but the old is reconfigured by the new. That is, neither the new learning nor the old knowledge is literally assimilated, so the new information assimilated makes the previous knowledge more stable and complete.

Fig. 1. a) Plasmonics for Dummies assessment structure. b) Classification of questions.



Accordingly, we will conduct a study to determine how the videographic material affects the significant learning of the subjects of study. To that end, we have devised an assessment to be applied as a diagnostic test to two groups of students: a focal group on which the intervention with videographic material will be carried out, and a reference group on which the base manuscript will be intervened. Following the intervention in the two groups, this assessment will be repeated in order to perform the corresponding analysis and identify differences in performance between the two groups in comparison to the diagnostic tests, and thus conclude on the actual impact that the material may have on the significant learning of the students. As a result, the test is geared toward solving problem approximations related to learning in science processes, in which the intervention of complex thought processes rather than merely memoristic learning is taken into account. To that end, we devised an assessment based on two interviewed taxonomies: *topic* and *cognitive*, and divided into two difficulty levels, as shown in Fig. 1. In this sense, the evaluation consists of a set of problems that have been meticulously classified into each taxonomy. The elements in the *topics* taxonomy are the subfields of plasmonics in which the problem is subscribed, namely: Refractive Index and Light Propagation (RI-LP), Snell Law: reflexion and refraction (SL:RR), Total Internal Reflection and Evanescent Waves (TIR-EW), Collective Electron Oscillations and Surface Plasmons (CEO-SP), and Standing Waves and Localized Surface Plasmons (SW-LSP). The *cognitive* taxonomy elements refer to the thinking skills involved in problem solving, namely: Interpretation and Creation of Representations (IC-R), Statement of Hypothesis (SH), and Recognition of Relevant Variables, Parameters, and Information (RR-VPI). These two taxonomies are not thought to be comprehensive or complete descriptions of scientific knowledge in the field of plasmonics. Instead, they are selected taxonomies that roughly cover the most important components of the field's learning processes. Furthermore, we envision two levels of difficulty: *beginner* and *basic*, with the goal of better understanding the students' learning process. The *beginner* level is concerned with problems in which the solution claims the understanding of a single concept and the commitment of a single dominant cognitive process, whereas the *basic* level is concerned with problems in which the solution comprises more than one concept or law, as well as the collaboration of two or more cognitive processes, none of which clearly dominant. These difficulty criteria, as well as the problem classification, are evaluated by experts who analyze and describe the entire solution process from their perspective. When the classification of the items causes significant debate, a third-party non-expert student is interviewed and asked to solve the problem using the thinking aloud protocol [6]. These techniques enable us to identify the critical points that students must pass through in order to reach the solution, as well as gain additional insight into the item's characterization within the assessment structure.

For ease to analyse the results, we have designed the problems with multiple choice questions with only one correct answer. The incorrect answers were purposefully designed to allow us to identify the difficulties in solving the problem and, as a result, characterize the student's level of comprehension. In order to investigate a broader range of possible outcomes, open questions were included in some cases, though the results will not be considered in the

assessment analysis. The first part of the test accounts on a total of twenty items to assess the first two *topic* taxonomies, namely: RI-LP and SL:RR. The total number of items are distributed into the *cognitive* taxonomies as indicated in Table 1. The remainder of the test, pertaining to the other two topic taxonomies, is in the works, and we hope to have the entire test completed by the end of this academic year in order to implement the previously mentioned study of the actual impact of the collection.

Table 1. Distribution first assessment questions.

Cognitive Taxonomy		Topic Taxonomy				
		Refractive Index	Reflection P.	Refraction P.	Snell's law	#Q
IC-R		x		x		1
					x	2
			x			3
SH					x	4
			x			5
		x		x		6
RR-VPI		x				7
					x	8
		x		x		9
		x			x	10

a. Beginner level questions

Cognitive Taxonomy		Topic Taxonomy				
		Refractive Index	Reflection P.	Refraction P.	Snell's law	#Q
IC-R		x		x	x	11
		x		x	x	12
			x		x	13
SH		x		x		14
			x	x		15
		x		x		16
RR-VPI		x			x	17
				x	x	18
		x		x		19
		x	x		x	20

b. Basic level questions

4. Conclusion and perspectives

We present a set of four video clips designed to help first-year undergraduate science and engineering students learn the fundamentals of plasmonics. The videographic content is available on the internet. The material is accompanied by a manuscript that describes the corresponding topics in great detail. We also presented the design of a future study to determine how videographic material affects significant learning of the subjects of study. This design includes the concept of an educational assessment based on two interviewed taxonomies and divided into two difficulty levels, with a total of twenty multiple-choice questions with only one correct answer. The full test, as well as the findings of the impact study, will be the subject of our upcoming publication.

5. References

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