



### Traditional versus hypertextual index in an on-line course on Oscillation and Wave Physics

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## Traditional versus hypertextual index in an on-line course on Oscillation and Wave Physics

**Abstract:** We describe an on-line course on Oscillation and Wave Physics ([https://ocw.upc.edu/webs/42254/Acustica\\_EN/](https://ocw.upc.edu/webs/42254/Acustica_EN/)), also used within a first-year subject on General Physics in our engineering college. Especially, we describe a new hypertextual index, based on a concept map, and the students' response to this index as compared to a traditional index.

**Keywords:** hypertext; concept map; on-line course design; blended representations; self-directed learning.

### Introduction

We implemented an on-line course on Oscillation and Wave Physics intended as an introduction to acoustics, since it specifically addresses the wave nature of sound. This on-line course was also used in the framework of the compulsory first-year subject on General Physics in our engineering college. It is freely accessible as Open Course Ware of the first author's university under the web address [https://ocw.upc.edu/webs/42254/Acustica\\_EN/index.htm](https://ocw.upc.edu/webs/42254/Acustica_EN/index.htm) in English, with links to Spanish and Catalan versions.

In the implementation of the on-line course, we took account of the need to face prior ideas or misconceptions and to conform to the current knowledge about effective writing for digital media. In addition, the on-line course has been provided with two alternative types of index for accessing the different items: a traditional linear index, and an hypertextual index based on a concept map.

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3 The objective of this article is:

- 4 • to describe the main features of the on-line course as learning environment,  
5 specially the two types of index, and  
6
- 7 • to report on the students' response to the hypertextual index in comparison to  
8 the traditional one.  
9

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12 No previous implementation of a hypertextual index for a physics learning web site is  
13 known to us. This is the reason for our interest in studying the students' response.  
14

### 15 **Rationale for the Design of the On-Line Course – Resulting Main Features**

16  
17 Concerning the form, the on-line course web site was designed taking the known rules  
18 for building effective on-line courseware into account, including the use of hypertext  
19 whenever appropriate [1,2]. Particularly, the physics contents were divided into  
20 conveniently short web pages, so that, whenever possible, the main text fits the  
21 computer screen. In addition, a course unit should contain the main ideas and means to  
22 access more information on the content, instead of too many details resulting in the  
23 same students' level of achievement but with a significantly longer duration of the  
24 preparation [3]. According to the last quoted author, another essential design principle  
25 is the chapter ordering of the contents. This led to the introduction of a traditional  
26 sequential index or table of contents, which should provide both an overall view and  
27 an access to the many web pages through the corresponding links (Figure 1).  
28  
29

30 [Insert Figure 1 about here]

31  
32 Concerning the contents, the on-line course web site was also designed under the  
33 viewpoint of the conceptual change pedagogies [4-6], which also aim to face prior  
34 ideas or misconceptions, about sound in our case [7].  
35  
36

1  
2  
3 The problem of misconceptions about sound has been addressed repeatedly even at  
4 college or university level [8,9]. At this level, the main misconceptions are related to  
5 the sound nature and the sound propagation model, because of considering sound  
6 caused by air or medium particles advancing in the space, instead of the oscillation of  
7 the air or medium particles which propagates to the neighboring particles [10].  
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15 As a way to face this kind of misconceptions, some published remedial approaches  
16 have been implemented in our on-line course by means of multimedia resources right  
17 from the first web page. The first approach has been the use of bridging analogies in  
18 the form of blended representations, given the high efficiency reported by [11-14].  
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23  
24 Some examples of blended representations are the graphic and mathematical  
25 descriptions of oscillations (Figure 2) and sound wave propagation (Figure 3). Other  
26 multimedia resources used are short own-produced videos of hands-on experiments,  
27 e.g. about resonance (Figure 4), and embedded applets taken from the web, which  
28 meet established evaluation criteria [15-17].  
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36 [Insert Figure 2, 3 and 4 about here]  
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38

39 An efficient complementary remedial approach consists of practical activities of  
40 ongoing self-assessment [18], which is also applied in our on-line course by means of  
41 problem solving (with hints and results) and multiple-choice questions.  
42  
43  
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45

46  
47 Another resource of the conceptual change pedagogies is the use of concept maps, also  
48 used to remedy misconceptions [19,20]. Concept maps are graphical tools for  
49 organizing and representing knowledge. They include concepts, usually enclosed in  
50 boxes, and relationships between concepts represented by connecting lines. Words on  
51 each line, referred to as linking words or linking phrases, specify the relationship  
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3 between the two concepts. The concepts are represented in a hierarchical structure,  
4  
5 with the most general concepts at the top of the map and the more specific concepts  
6  
7 arranged hierarchically below [21]. Experimental results show that concept maps are  
8  
9 effective and useful for teaching concepts and increasing the students' level of factual  
10  
11 knowledge in spite of some difficulties [22-25]. Concept maps are also useful as  
12  
13 assessment tool for conceptual understanding in different knowledge areas [26-28].  
14  
15

16  
17 This suggested the possibility of giving the on-line course the structure of a fully  
18  
19 hypertextual environment on the basis of a concept map about Oscillatory and Wave  
20  
21 Physics for our engineering students. The linking phrases between nodes were  
22  
23 implemented as guiding questions.  
24  
25

26  
27 This concept map was translated into a hypertextual index or table of contents (Figure  
28  
29 5, with fully expanded index), where every concept map node corresponds to a theory  
30  
31 item, i.e. a web page. The extension of the index can be adjusted by the user at will,  
32  
33 according to the desired hierarchical level, clicking on the yellow cases with a plus or  
34  
35 minus sign (for expanding or contracting, respectively).  
36  
37

38  
39 [Insert Figure 5 about here]  
40  
41

42 Hypertexts are known to have some advantages as learning environments. They allow  
43  
44 the reader to develop a non-linear interaction with the content [29], including ways of  
45  
46 navigating the content [30,31]. This interaction can foster a flexible and nevertheless  
47  
48 deep learning [32] and increase readers' comprehension skills [33]. Hyperlinks  
49  
50 provide a high level of learners' control over the order and selection of information  
51  
52 through comprehension decisions [34,35]. A hierarchically structured arrangement  
53  
54 helps to understand and to solve problems [36], and to understand the macrostructure  
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3 of the semantic relationships between contents that supports more coherent navigation  
4  
5 and promotes the construction of a mental representation of the information structure  
6  
7 of hypertexts [37].  
8

### 9 10 **Traditional versus Hypertextual Index – Students’ Response**

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12 As mentioned in the Introduction, the second objective of this article is to report on the  
13  
14 students’ response to the hypertextual index in comparison to the traditional one.  
15

16 Specifically:

- 17  
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19  
20 a) Which advantages and drawbacks do students find in the hypertextual index in  
21  
22 comparison with the traditional index? (qualitative comparison)  
23  
24  
25 b) Is there any relationship between the use of one or the other index and the  
26  
27 performance in the exams? (quantitative comparison)  
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29

### 30 ***Students’ Populations***

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32 In a first phase covering four semesters, this on-line course on Oscillation and Wave  
33  
34 Physics was an essential part of a wider on-line distance learning course on Acoustics.  
35  
36 This part of the on-line course was accessible only through the hypertextual index  
37  
38 (Fig. 5). The rest of course syllabus was related to more specialized areas like  
39  
40 environmental acoustics, musical acoustics and architectural acoustics, and it was  
41  
42 accessible only through a traditional index (similar to Fig. 1). This course was for  
43  
44 senior students enrolled in different engineering programs, ranging from  
45  
46 Telecommunication to Chemistry. These students, 45 in total, formed the population  
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48 taken for the above question a).  
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3 Later, in a second phase, this on-line course was used in the framework of the  
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5 compulsory first-year subject on General Physics in our engineering college, for the  
6  
7 topic of Oscillation and Wave Physics. Specifically, it was used as environment for  
8  
9 autonomous learning at home previously to the traditional face-to-face teaching in a  
10  
11 sort of flipped classroom. So, the students had to learn the theory items scheduled for  
12  
13 the corresponding class autonomously in advance to the class, using the on-line course.  
14  
15  
16 In the class itself, only unclear concepts were clarified and, especially, the problems  
17  
18 and multiple-choice questions proposed in the on-line course itself were solved. Of  
19  
20 course, the on-line course was also recommended as a learning support for reviewing  
21  
22 the contents after the class and preparing the exam. From all the involved freshmen  
23  
24 students, we discarded those who did not even take the exam or who reached less than  
25  
26 10% of the maximum score, because it could be assumed that they had not worked  
27  
28 minimally on the subject. As a result, 207 students in five semesters formed the  
29  
30 population taken for question b) (96 in the first three semesters, plus 111 in the  
31  
32 following two semesters).  
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### 38 ***Methodology***

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41 Concerning question a), at the end of each course in the first phase, students were  
42  
43 asked to comment one or more aspects taken at will from a list of possible aspects of  
44  
45 the on-line course. One of these aspects to comment just if desired was the comparison  
46  
47 of the study using the web pages accessible through the hypertextual index with the  
48  
49 study of the rest of the course using the web pages accessible through a traditional  
50  
51 index. The freedom to comment this particular aspect should avoid that students feel  
52  
53 compelled to make any stereotyped comments about such a difference, which probably  
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would not reflect their true learning experience. Indeed, only a limited number of students, 21 out of 45, made a comment on this specific aspect. Additionally, some of the comments were taken from the discussions within the working groups formed.

Concerning question b), in the first three semesters of the second phase (96 students), only the traditional index was made available. In contrast, in the two subsequent semesters (111 students), only the hypertextual index was available. Then, we compared the performance in the five final General Physics exams with regard to the topic of Oscillations and Waves as a relevant part of these exams.

As a measure of every student's performance, which we call 'Performance Rate', we have taken the ratio of the sum of scores reached in each multiple-choice question or problem-solving item concerning Oscillations and Waves to the sum of the respective maximum scores. Each problem-solving item had a maximum score of 1, and each right answer to a multiple-choice question had a fixed score of 0.5 (-0.17 if wrong). Nevertheless, here we have taken 0 as score both for unanswered multiple-choice questions and wrong answers.

### ***Results for Question a) – Discussion***

Students as a whole do not clearly show a preference for the one type of index to the detriment of the other one, but they point out their advantages and drawbacks according to their learning experience.

Advantages of the hypertextual index (with students' literal expressions, translated into English):

1) To raise the students' curiosity and therefore their interest for the physics contents:



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2  
3 The order of the topics was chosen according to my curiosity [...] (Electrical  
4  
5 Engineering student).

6  
7  
8 [...] one can gradually evolve and learn according to one's own taste. In other  
9  
10 words, choosing the order of topics by oneself makes it more entertaining,  
11  
12 because it is always simpler to learn what one likes just then. (Industrial  
13  
14 Engineering student).

15  
16  
17 The main advantage of the hypertextual system is the alternative "playful" way  
18  
19 of studying (discussion in one of the working groups).

## 2) Efficiency of the guiding questions of the hypertextual index in guiding the student:

20  
21  
22  
23 The criterion [for the order to be followed] was to try to always follow the flow  
24  
25 lines, in order to try to move forward in the theory without losing sight  
26  
27 (Mechanical Engineering student).

28  
29  
30 [...] the order I followed was very coherent, thanks to the help of the questions in  
31  
32 black [guiding questions] and the flow lines, I must admit (Mechanical  
33  
34 Engineering student).

35  
36  
37  
38 Once I have seen how the synoptic [hypertextual] index was structured, it was  
39  
40 easier to choose the order [...], always trying to follow one and the same line of  
41  
42 knowledge, without going into items which could be more interesting a priori,  
43  
44 but which diverted from a logical line [...]. Once I understood the structure of the  
45  
46 synoptic [hypertextual] index, I found it much easier and more pleasant to choose  
47  
48 the items to be studied. The method of following a preset order [traditional  
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3 sequential index] makes the task much easier, although it takes away some of its  
4  
5 attractiveness when studying the topics (Mechanical Engineering student).  
6  
7

8 3) Freedom to pursue one's own learning itinerary according to the personal leanings,  
9  
10 so that physics becomes less hard or laborious:  
11

12  
13 The detail that most attracted my attention was the freedom to choose the next  
14  
15 item to be studied [...] (IT Engineering student).  
16  
17

18 [...] it is easier to follow a predetermined index, but it may become harder. It is  
19  
20 more autodidactic to follow a synoptic [hypertextual] index, so you are choosing  
21  
22 the way according to your needs (Mechanical Engineering student).  
23  
24

25 [...] in the form of a synoptic chart, it offers more freedom so that one can  
26  
27 organize the contents at will or according one's interest (Electrical Engineering  
28  
29 student).  
30  
31

32  
33 4) To learn to avoid any obsession with the order of items, as a convenient attitude in  
34  
35 order to learn autonomously:  
36  
37

38 [Concerning the study of the different contents,] sometimes my impression was  
39  
40 that I was not doing it in the right order [...], but afterwards I got used to  
41  
42 understand it in a parallel way and not to become obsessed with an allegedly  
43  
44 correct order (Telecommunications Engineering student).  
45  
46

47  
48 It is very constructive to learn in this way, because the doubts arise before the  
49  
50 answers (Industrial Engineering student).  
51  
52

53 Another advantage [or the hypertextual index] is the possibility of rectifying, that  
54  
55 is to say, if one has chosen an item and afterwards one is not sure about it, one  
56  
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58

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2  
3 can leave it and choose a more suitable one (discussion in one of the working  
4  
5 groups).

6  
7  
8 Drawbacks of the hypertextual index:  
9

10  
11 1) Possible poor interpretation of the hierarchical order of items:  
12

13 We agree about the convenience [...] of indicating somehow which items are the  
14  
15 most important [...] and which are minor (discussion in one of the working  
16  
17 groups).  
18  
19

20  
21 2) Possibility of interpreting the guiding questions in an equivocal manner:  
22

23 The [guiding] questions should be as accurate as possible, allowing [...] to get an  
24  
25 idea of the contents [...]. Everyone can interpret this guiding questions in a  
26  
27 different way, obtaining a “pleasant” or “unpleasant” result once the content  
28  
29 hidden in the item becomes disclosed (Telecommunications Engineering  
30  
31 student).  
32  
33

34 Although [the guiding questions] lead you towards which web page [you want to  
35  
36 go], it is not clear enough what will be explained there and which background  
37  
38 you need (discussion in one of the working groups).  
39  
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42 The help of the introductory questions was limited and, in practice, in order to  
43  
44 know the content of an item, we rather tended to have a look at it, because in our  
45  
46 opinion, a question can be misread (discussion in another working group).  
47  
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50  
51 3) Uncertainty about whether the optimal item order is being followed (with the more  
52  
53 or less implicit statement that the order proposed by the lecturer is the optimal one):  
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3 [...] but at the same time it created a sense of insecurity for me about whether the  
4  
5 path chosen was the most suitable one (IT Engineering student).  
6

7  
8 [...] Instead, when we use the second method [traditional index], we are  
9  
10 absolutely sure that the topics we address will be within our grasp, because the  
11  
12 lecturer has scheduled the topics adequately (discussion in one of the working  
13  
14 groups).  
15

16  
17 [With the traditional index,] the student is assured that he or she will not take the  
18  
19 wrong path, but all the pieces will fit together if he or she follows this index and  
20  
21 if the author has done his or her work well (discussion in another working  
22  
23 group).  
24  
25

26  
27  
28 4) Possible waste of time when a topic must be left aside, for addressing a previous  
29  
30 topic needed:  
31

32  
33 [...] sometimes you can make a wrong choice and you have to turn to previous  
34  
35 topics that would be already studied if you had used the second method  
36  
37 [traditional index]. The second method is quicker, because you don't need to  
38  
39 search, turning to previous topics, and you have not so many doubts arising  
40  
41 (Industrial Engineering student).  
42  
43

44  
45 For example, to solve problem 7.6 of the item "The decibel", one needs to have  
46  
47 seen the item "Sound intensity as a function of distance", but I saw it later [...].  
48

49 To do some exercises, I had to know the theory that I would see afterwards. [...]

50 It is possible that, in order to understand a concept, one has to have previously  
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3 understood another concept not yet seen (my own experience) [...] (Electronic  
4  
5 Engineering student).

6  
7  
8 [...] it is difficult to deduce from a title what should be done first and what  
9  
10 shouldn't. So, I found myself studying topics for which other topics were needed  
11  
12 on which I hadn't worked (Electrical Engineering student).

13  
14  
15 Out of these possible drawbacks, the second one is unavoidable, because of the always  
16  
17 limited information that a guiding question can convey, necessarily being a short  
18  
19 question. However, these comments must be taken into account in order to put guiding  
20  
21 questions which are not purely rhetorical but convey the maximum possible  
22  
23 information on the content or approach of an item.  
24  
25

26  
27 The other drawbacks must be put into perspective, particularly the third one. The  
28  
29 learning method using a traditional sequential index will always give a greater sense of  
30  
31 security than the hypertextual index, because the freedom of choice very often has the  
32  
33 price of uncertainty to a greater or lesser extent. This freedom of choice can be  
34  
35 considered as a part of autonomous learning, and therefore, it is considered as a  
36  
37 disadvantage by students, together with a greater workload [38]. Students are used to  
38  
39 the teacher or lecturer as a provider of subject content who needs to fill the students  
40  
41 with knowledge [39,40], and they find it hard to learn and work autonomously,  
42  
43 developing their own responsibility for learning in tertiary and lifelong education  
44  
45 [41,42]. However, self-directed learning throughout a lifetime should take the freedom  
46  
47 of choice into account as an important value [41,43]. The freedom and choice features  
48  
49 provided by new self-directed personalized learning environments should be  
50  
51 maintained as a support of the constructivist approach and self-regulation, even while  
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3 sustaining the appropriated level of teacher's or lecturer's control and structural  
4  
5 requirements of formal learning [44]. In addition, freedom and choice for learning is  
6  
7 one of the factors leading to success or personal change. Indeed, in a study with self-  
8  
9 directed learners [45], personal freedom to learn was rated most important for success  
10  
11 and personal transformation, and also choice was a key aspect of using open  
12  
13 educational content. Choice or freedom to select the topic is also an essential  
14  
15 motivational reason for self-directed informal learning, the freedom to learn being a  
16  
17 key factor for its success [46]. Therefore, the perception of uncertainty resulting from  
18  
19 the freedom to choose a personal path through the hypertextual index of contents  
20  
21 cannot be considered a learning disadvantage with respect to the traditional index.  
22  
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Al other drawbacks reported were also taken into account for the final version of the  
hypertextual index used in the second phase. However, these drawbacks remain  
unavoidable to some minor degree.

### ***Results for Question b) – Discussion***

As a first result, we found no significant difference between the students' performance  
rate as a whole using the traditional index and using the hypertextual index, with mean  
values and 95% confidence intervals of  $0.52 \pm 0.04$  and  $0.53 \pm 0.04$ , respectively.

However, a closer look at the individual results suggested that each performance rate  
could depend on the particular aspect of the Oscillations and Wave topic addressed by  
the corresponding individual multiple-choice question or problem-solving item.

Therefore, we established the five subtopics of the Oscillations and Wave topic listed  
in Table 1. We found no significant difference between using the traditional index and

1  
2  
3 the hypertextual one for all subtopics, except for No. 3 and 4 in Table 1, where the  
4  
5 respective mean performances and their 95% confidence intervals are given.  
6

7  
8 [Insert Table 1 about here]  
9

10 All performance rates are around 0.5, after excluding the students with an exam score  
11  
12 under 10% of the maximum, as explained in the Methodology subsection above.  
13

14  
15 For subtopics 1, 2 and 5, the absence of significant differences in the performance rate  
16  
17 can be due to the lack of learning advantages of one type of index over the other one in  
18  
19 these subtopics. Indeed, the different issues in these subtopics can be treated in a rather  
20  
21 linear way, i.e. with no direct need to consider any relevant interrelationships with  
22  
23 issues belonging to other subtopics. In this case, the traditional linear index should not  
24  
25 be at a disadvantage compared to the hypertextual index, at least with regard to taking  
26  
27 exams.  
28  
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30  
31  
32 In contrast, in subtopics 3 and 4 there are cross-linked relationships between different  
33  
34 conceptual aspects, and these relationships should be addressed as explicitly as  
35  
36 possible for a better understanding. This is obviously the case for the relationship  
37  
38 between the wave as a whole and the local oscillations at the different points of a wave  
39  
40 propagation medium, and it also applies for the close relationship between the local  
41  
42 oscillation energy and the energy propagation in a wave, together with the resulting  
43  
44 wave intensity in the case of acoustic waves. Here, the concept map which is behind  
45  
46 the hypertextual index was most probably a relevant help for building deeper  
47  
48 knowledge concerning these interrelationships, according to the considerations in the  
49  
50 Rationale section, based on the literature about concept maps (especially [21-24]).  
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Another reason for the absence of significant differences in some performance rates could be the teaching method described in the Students' Populations subsection. Indeed, in the sort of flipped-class approach applied, the autonomous learning using the on-line course was followed by a face-to-face class with complementary activities like clearing up of doubts or problem solving. This can be expected to have evened out the differences to some extent. However, for subtopics 3 and 4, the significant performance differences reveal that the use of the concept map in the form of an hypertextual index has probably led to a deeper assimilation or internalization of the above-mentioned interrelationships between conceptual aspects which could not be reached in the face-to-face class activities, according to the literature quoted above on conceptual maps.

## Conclusions

In a first phase, the on-line course was used with the hypertextual index for the Oscillations and Waves topic as introduction to a wider subject on Acoustics, but using a traditional index for the rest of this subject. As a qualitative student response, we collected the free comments made (if desired) by students on the difference in using each type of index. Students found some advantages of the hypertextual index, e.g. the ability to rise curiosity increasing interest in the physics contents, or the building of a convenient attitude for learning autonomously. In contrast, the drawbacks perceived were e.g. the possible equivocal interpretation of the guiding questions, or the uncertainty about the optimal order of items to be followed.

In the Discussion of these qualitative results, these perceived drawbacks have been put into perspective, as an unavoidable part of a more autonomous and self-directed



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3 learning in comparison to the externally directed learning through a traditional  
4 sequential index, resulting in indirect advantages for a self-directed personalized  
5 learning, according to the literature quoted there.  
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9

10 In a second phase, the on-line course was used for the topic of Oscillation and Waves  
11 within the first-year subject on General Physics, in a sort of flipped-class approach,  
12 where students had to learn the contents autonomously before the face-to-face class.  
13  
14

15 The course version with only the traditional index was available in some of the  
16 semesters, while the course version with only the hypertextual index was available in  
17 the other semesters. As a quantitative student response, no significant overall  
18 performance difference in the exams was observed, if all Oscillations and Waves  
19 subtopics as a whole are considered. However, we found a not large but significant  
20 difference for two subtopics related to cross-linked relationships between different  
21 conceptual aspects, like the relationship between local oscillations at the different  
22 points of a wave propagation medium and the wave as a whole, and also between local  
23 oscillation energy and energy propagation in a wave, including wave intensity. The  
24 lack of a more extensive significant performance difference is compatible with a lack  
25 of advantage of one index over the other with regard to taking exams. It can also be  
26 explained by some evening-out effect of the complementary face-to-face activities. In  
27 contrast, for both above-mentioned subtopics, the significant performance differences  
28 can be explained by a deeper internalization of those above-mentioned cross-linked  
29 relationships through the concept map underlying the hypertextual index, according to  
30 the literature.  
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(Block 1)			
<b>Topic 1</b>	<b>Undamped oscillatory phenomena</b>	Problems:	Questions:
	1. <a href="#">Introductory description of the simple harmonic motion</a>		
	2. <a href="#">Equations of the simple harmonic motion (using trigonometric functions)</a>	01 - <a href="#">01</a> , <a href="#">02</a> , <a href="#">03</a> , <a href="#">04</a> ,	01 - <a href="#">01</a> , <a href="#">02</a> , <a href="#">03</a> , <a href="#">04</a> , <a href="#">05</a>
	3. <a href="#">Undamped oscillatory phenomena in general : Fourier analysis</a>	<a href="#">05</a> , <a href="#">06</a> , <a href="#">07</a>	
	4. <a href="#">Energy of a simple harmonic motion</a>		
<b>Topic 2</b>	<b>Damped and driven oscillatory phenomena</b>	Problems:	Questions:
	1. <a href="#">Damped oscillatory phenomena</a>		
	2. <a href="#">Driven oscillatory phenomena (description)</a>	02 - <a href="#">01</a> , <a href="#">02</a>	02 - <a href="#">01</a>
	3. <a href="#">Driven oscillatory phenomena (amplitude and power) and Resonance</a>		
<b>Topic 3</b>	<b>Sound as an oscillatory phenomenon</b>	Problems:	Questions:
	1. <a href="#">Description of sound as a local oscillatory phenomenon</a>		
	2. <a href="#">First attribute of sound: pitch</a>		
	3. <a href="#">Second attribute of sound: timbre - main feature</a>	03 - <a href="#">01</a> , <a href="#">02</a> , <a href="#">03</a>	03 - <a href="#">01</a> , <a href="#">02</a> , <a href="#">03</a> , <a href="#">04</a> , <a href="#">05</a> , <a href="#">06</a>
	4. <a href="#">Second attribute of sound: timbre - secondary feature</a>		
	5. <a href="#">Noise: a frequent special component of sound</a>		
	6. <a href="#">Third attribute of sound: loudness</a>		
(Block 2)			
<b>Topic 4</b>	<b>Wave phenomena</b>	Problems:	Questions:
	1. <a href="#">Phenomenological description of the wave phenomena</a>		
	2. <a href="#">Descriptive quantitative concepts</a>	04 - <a href="#">01</a> , <a href="#">02</a> , <a href="#">03</a>	04 - <a href="#">01</a> , <a href="#">02</a> , <a href="#">03</a>
	3. <a href="#">Equation of the harmonic wave</a>		
	4. <a href="#">Basic types of waves: transverse waves and longitudinal waves</a>		
<b>Topic 5</b>	<b>Laws of wave propagation</b>	Problems:	Questions:
	1. <a href="#">Huygens-Fresnel principle</a>		
	2. <a href="#">Law of reflection</a>	05 - <a href="#">01</a> , <a href="#">02</a> , <a href="#">03</a> , <a href="#">04</a>	05 - <a href="#">01</a> , <a href="#">02</a>
	3. <a href="#">Law of refraction</a>		
<b>Topic 6</b>	<b>Superposition of waves</b>	Problems:	Questions:
	1. <a href="#">Superposition principle</a>		
	2. <a href="#">Interference of waves of the same frequency: mathematical description</a>		
	3. <a href="#">Positions of the maxima and minima</a>		
	4. <a href="#">Diffraction</a>	06 - <a href="#">01</a> , <a href="#">02</a> , <a href="#">03</a> , <a href="#">04</a>	06 - <a href="#">01</a> , <a href="#">02</a> , <a href="#">03</a> , <a href="#">04</a> , <a href="#">05</a>

Figure 1: Traditional sequential index or table of contents for accessing the different web pages (theory items and self-evaluation activities).

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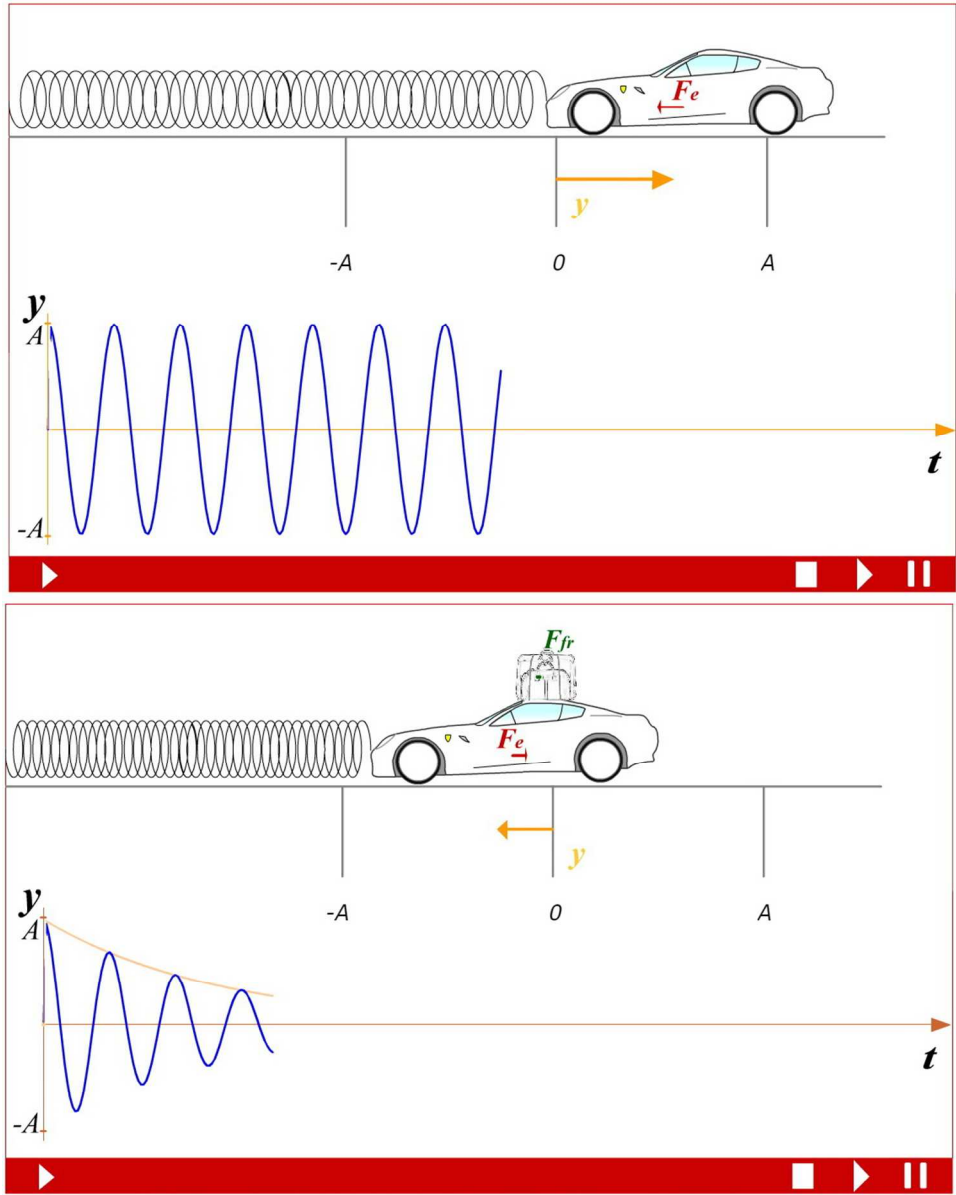


Figure 2: Embedded Adobe Flash animations with blended representations of oscillations (top: simple harmonic motion, bottom: damped oscillation).

402x502mm (72 x 72 DPI)

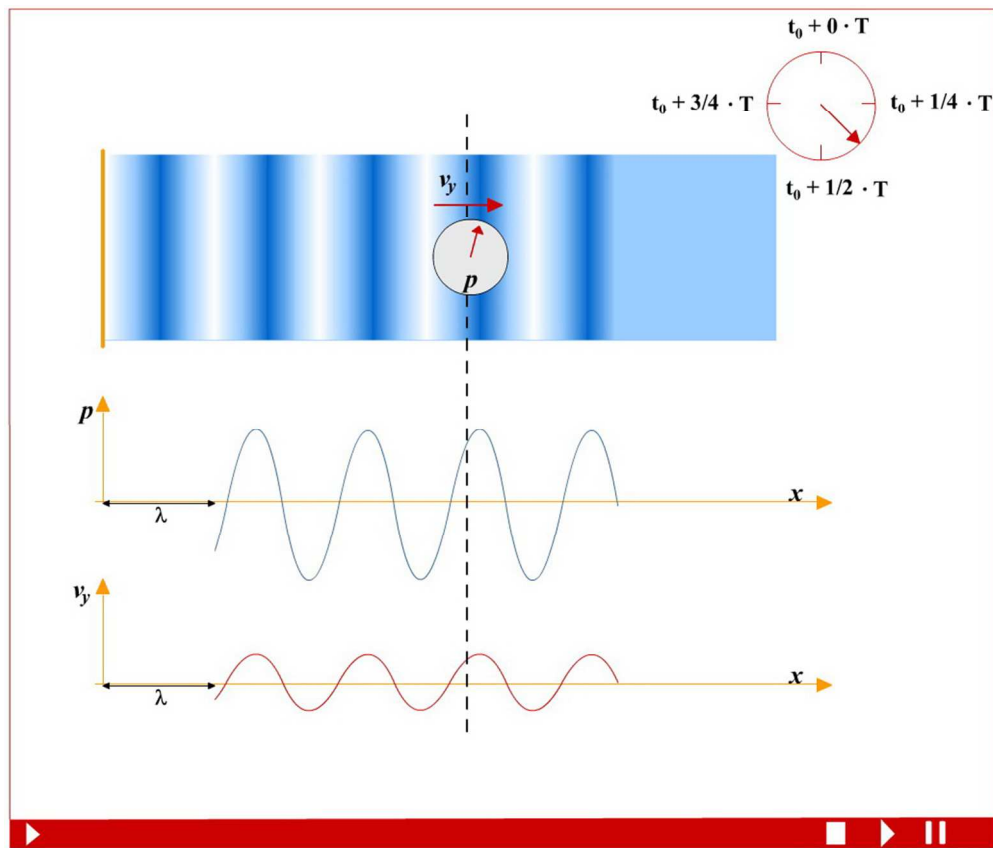


Figure 3: Embedded Adobe Flash animation with a blended representation of a propagating sound wave.

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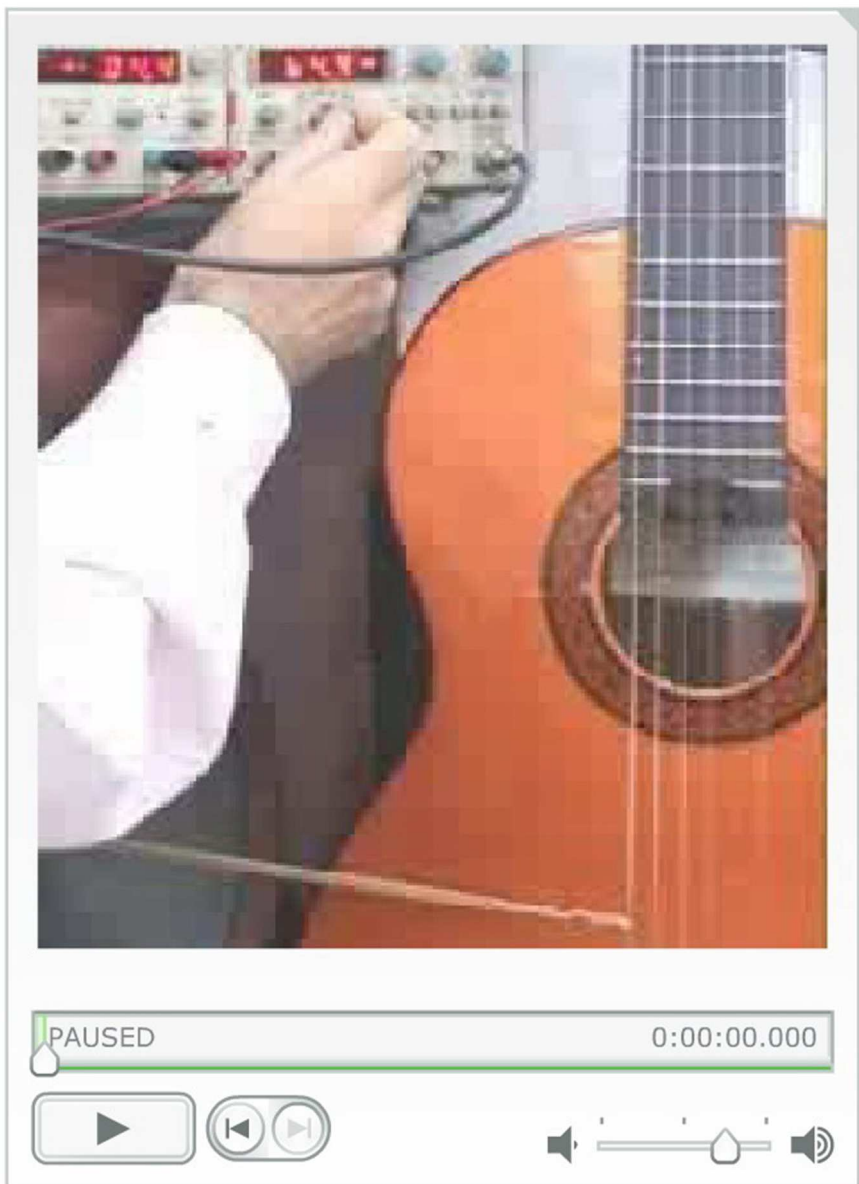


Figure 4: Embedded Adobe Flash video of a hands-on experiment about resonance.

233x320mm (72 x 72 DPI)

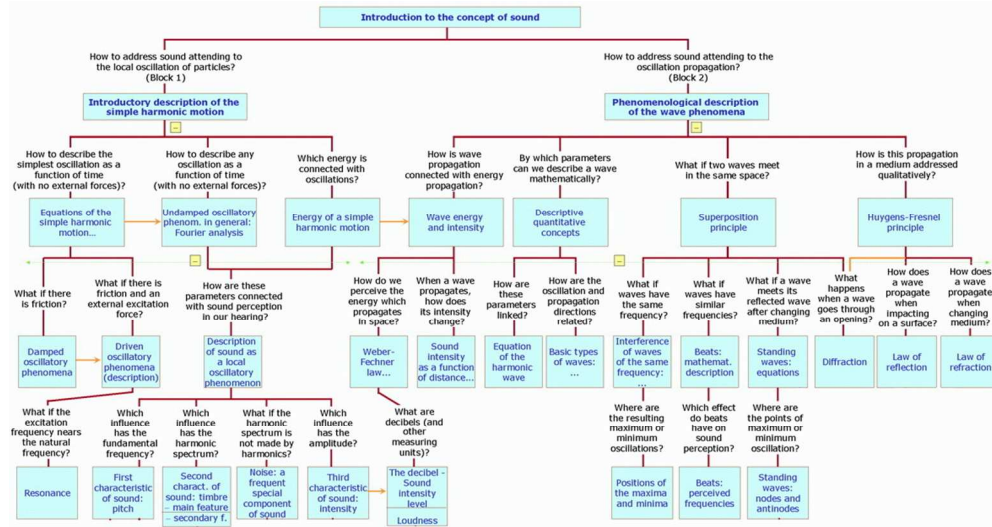


Figure 5: Hypertextual index (fully expanded) based on a concept map, for accessing the different items.

418x222mm (72 x 72 DPI)

Table 1. Performance Rate (ratio between the sum of scores reached and the sum of maximum scores) for each subtopic of Oscillations and Waves (significant difference in the shaded areas).

Subtopic	Performance Rate	
	with traditional index	with hypertextual index
1. Equation of motion for harmonic oscillations	$0.60 \pm 0.06$	$0.51 \pm 0.07$
2. Equation of motion for harmonic waves	$0.5 \pm 0.1$	$0.53 \pm 0.06$
3. Relationship between oscillations and waves	$0.50 \pm 0.06$	$0.63 \pm 0.06$
4. Energy of oscillations and waves, and sound intensity	$0.45 \pm 0.08$	$0.60 \pm 0.07$
5. Superposition of waves	$0.53 \pm 0.04$	$0.48 \pm 0.09$

For Peer Review