A "Horizontal" Study of Impedance, found in Different Chapters in Physics Educational Curricula, utilizing Hands-on Experimentation and Educational Simulation

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Abstract. *In this paper, the proposal and the results of formative evaluation of application of "horizontal" Laboratory of Natural Sciences are presented. The exercises and the educational activities in this laboratory are not included in one thematic unit (as they are structured in corresponding laboratories) but are structured so as to study the concept of impedance in many different units of Physics.*
The concept impedance ("empedesi" in Greek) emanates from the word [pedi] = brake and it expresses precisely its natural importance attributing a more general significance that we meet in a variety of thematic areas of physics:

$$impedance = \frac{reason}{result}$$

Key words: Impedance, Horizontal approach, Laboratory activities.

1. Introduction – Framework

It is well known that in our country the science laboratories, in all departments of higher education, are structured in a certain way so that they include thematic exercises related to individual units and subject areas of science (e.g. thermodynamics, mechanics, optics...).

In this paper the proposal and the results of formative evaluation of the implementation on a "Horizontal" Science Laboratory applied to students are presented, emphasizing on the concept of impedance.

In this (horizontal) laboratory, all the exercises and the activities are not included in a certain theme (as in other laboratories) on the contrary; they are formulated to study the concept "impedance" through various natural phenomena. Ultimately, the students can achieve the widest possible understanding of natural phenomenon that includes this particular concept.

The term "impedance" refers to a physical concept which turns up in a number of Physics' subjects and not only in some of them, as it is taught mainly in Higher Education.

Table 1. The formula of impedance in the different chapters of Physics

1	Mechanical impedance (waves)	$\frac{F(\text{Force causing oscillation})}{u(\text{speed oscillation})}$
2	Electrical impedance	$\frac{V(\text{voltage})}{\text{I(Electricity)}}$
3	impedance (in channel flow)	$\frac{\text{P (Pressure)}}{\Pi\text{ (provide)}}$
4	Acoustic impedance	$\frac{\text{P(r, t) (Pressure)}}{\text{u(r, t) (particle velocity)}}$

There is also a general formula that can be used to describe impedance:

$$impedance = \frac{reason}{result} \quad (1)$$

The objective of the application presented in this paper is to propose exercises and experimental activities targeted in the deeper understanding of the physical concept of impedance, in a laboratory environment, where experiments and simulations are applied.

2. Rationale – Research Question

Two exercises were formulated following the rationale of the "horizontal'' laboratory [2] at the

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Science, Technology and Environment Laboratory in The Department of Education at the University of Athens, related to impedance and were put in to practice with the help of postgraduate students. For the needs of these exercises, appropriate materials have been used, developed firstly to support and secondly to ensure an effective educational laboratory intervention.

The research question is: Is it possible for the students to comprehend the meaning of impedance using a horizontal laboratory rationale and finally concluding that impedance can be described as it is in (1) ?

3. Methodology

Initially a questionnaire with general and particular questions for impedance was given to the students in order to have a first impression about their knowledge to the material at hand.

Table 2. Part of the given questionnaire

1	Do you know the physical meaning of the electrical impedance?
2	Do you think that the concept of impedance is present in some (more than one) thematic chapters/ themes/units of physics? If yes. Which?
3	The physical concept of impedance is the difficulty of something ... Give us examples.
4	Can you think kind of impedance other than electrical?
5	Can you give us a general formula for impedance?

All the worksheets in the experimental activities are structured with the following scientific / educational model by inquiry [5]:

1. Trigger of Interest
2. Hypothesis Expression
3. Experimentation
4. Conclusions
5. Generalisation

Post-graduate Physics department students were selected because they are more familiar with experimental procedures and they have been taught impedance during their university studies.

The students studied the concept impedance through the exercises and the appropriate worksheets.

The first application was an experiment about electrical impedance in a circuit of AC-impedance capacitor.

The second application was the study of the acoustic impedance through two simulations.

Post graduate students were divided into groups of two and worked on workshop benches equipped with the appropriate equipment for the experiment and computers (one per person) for the simulations.

Initially, a day or two before the intervention, a pre-laboratory preparation sheet was given to the students in order to familiarize them with the following process (experiment and simulation) and with certain terms related to the tasks.

The educational process is structured following these steps:

Trigger of Interest: In order to stimulate the interest of students, in the worksheet were included pictures and text about the general concept of impedance.

Hypothesis Expression: In this step the students have to construct the formula of "impedance" as a result of simple questions and given examples.

Experimentation: In this step of the experimentation, the instruments and the apparatus of the experimental device are described. Initially there is an introduction about each instrument and the equipment used for assembling the experiment. For this reason, on the worksheet there is only the display of instruments and materials used and a brochure about the operation and detailed description of the oscilloscope (if needed). The students should assembly the instruments, the equipment and the materials as given in the description of the circuit.

After that, students record and process the experimental measurements.

Conclusions: During this step students manage to work out their conclusions which are related to electrical impedance. Which natural size represents the reason and which natural size the result, in electrical impedance.

Generalization: Finally the students observed data from various fields (such as technology, medicine) in technological applications which were presented in the worksheet. Through these elements, students succeeded to generalize what was studied in the previous steps.

The second application is about two simulations which deal with acoustic impedance. It is difficult to observe acoustic impedance under normal laboratory conditions (i.e.

expensive devices for the given experiment), so the simulation was chosen as the best way for the students to understand in a short time the natural phenomenon.

The purpose of simulation is to understand the concept of acoustic impedance and particularly how this physical size changes with the alteration of material diffusion of sound. Also with the simulation software, students can intervene and change the various parameters to obtain different results.

With a worksheet structured analogically to the previous one, students deal with acoustic impedance.

Particularly for each step:

Trigger of Interest: In order to stimulate the interest of students, in the worksheet were included pictures and text about the general concept of impedance.

Hypothesis Expression: During this phase, the students answered a series of questions on acoustic impedance.

Experimentation: During this phase the experimentation dealt with alternating the parameters and the energy study of acoustic impedance through the selection of various materials.

Conclusions: During this step students manage to work out their conclusions which are the following: what is the reason and which is the result in an acoustic system in order to achieve acoustic impedance, how it changes with relation to the changes in the transmitting material of sound and of other parameters. Students derive a formula for acoustic impedance.

Generalization: Finally, students deal with the implementation of acoustic impedance as it is used in ultra sound diagnosis. The purpose of this was to gain a global perspective of acoustic impedance which is applied in the medical field.

Following the educational intervention and after two weeks the students were given the same questionnaire -Table 2- and asked to answer the questions again.

4. Results

Both applications flew smoothly with no significant problems. All the students through experimentation concluded to the main formula for electrical and acoustic impedance.

Postgraduate students showed great interest in the “horizontal laboratory” and its experimental activities which generally is accepted as an important motivation for learning.

The students dealt with a number of minor problems, such as operating some electric equipment. These technical problems are understandable if we consider that students do not have much experience from laboratory experiments in general. Firstly it is well known that Greek secondary schools are not familiarized with laboratory experiments as an additional method of teaching the physical phenomena and concepts. Secondly in post-secondary education (most of the times) the whole intervention seems to be an evaluation/access procedure rather than an educational process of familiarization with apparatus, experimental devices and understanding of science concepts/phenomena.

The use of simulations in order to understand the concept of acoustic impedance seems to be very helpful because the students can quickly approach the concept of acoustic impedance as they can easily change parameters and immediately check their hypotheses.

It should also be mentioned that students showed significant comfort using computers, which is probably the result of the spreading use of computers, not only in everyday life but also in the educational process, especially the last few years.

5. Conclusions – Proposals

In the present study, an innovative application of the horizontal laboratory has been established.

We can say that the first signs from the application are encouraging. Of course we must admit that after every educational intervention students’ understanding about particular concepts and phenomena seems to be in a higher level. And this was clear evident in our case too.

But through the completed questionnaire (given two weeks after the intervention we must mark) which show us significant change to their knowledge about impedance and our own observations / questions (during the procedure) it seems that students reinforced to relate impedance with difficulty in all themes.

In addition through the above training and experimental teaching methods students were lead to generalization of the concept in some areas of physics using the formula (1) which will eventually help students to comprehend -better than ever- the concept of impedance.

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