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FISICAONDEMUSICA: A WEB ENVIRONMENT ABOUT WAVE PHYSICS AND MUSICAL ACOUSTICS

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Abstract

The web site http://fisicaondemusica.unimore.it, presented in this paper, was created by the author with the goal to stimulate the approach of young people to the study of Physics. The main concepts of wave physics are illustrated in a non-standard way by means of the joint use of animations, audio samples, texts, and interactive simulations, and many real-world examples mainly in the field of musical acoustics are analyzed. The web environment extends over about 190 web pages including traditional modules, together with more than 1300 multimedia files and interactive simulations.

1. The project

The study of waves provides an invaluable set of tools to teach physics at every level, because of both the generality of the concepts and techniques involved, and the variety of phenomena described. Often, however, many textbooks lack effectiveness and appeal when illustrating this subject. In order to overcome these faults we have designed and built a web-site about physics of waves that allows users to easily and effectively visualize oscillatory phenomena by seamlessly integrating plain lessons with drawings, animations, sounds, and interactive programs. This approach allows to overcome the well known difficulty in visualizing phenomena that are widespread in space and depend on time. On the other hand, the natural curiosity and naive first person experience that people have got about music and sound are a good good starting point to move the first steps towards the scientific understanding of wave phenomena. The intuition can be stimulated and guided only by using appropriate tools, that need to go far beyond the standard "talk and chalk" school lesson. In fact non trivial real-world situations, simple enough to be investigated with elementary concepts and mathematical tools, yet interesting and significant both in a musical and a physical framework are quite rarely included in ordinary high school curricula, even though I consider them a great occasion to stimulate the interest of the students to a deeper level of understanding Nature.

This web project was initiated within the "Progetto Lauree Scientifiche" (PLS) at the "Dipartimento di Fisica dell'Università di Modena e Reggio Emilia", and with the support of the CNR-INFM National Research Center "S3". The development is being performed by Luca Antignani (composer), Luca Cattani (web developer), Andrea Spagni and Brunella Brunatti (high school teachers of Physics), Marcello Nuccio (software developer), Samuele Alberti (art), and by the author (main contributor and project leader).

In the planning phase of the project a test was prepared and administered to 305 high school students in Liceo Scientifico "Ariosto-Spallanzani", Istituto Musicale Pareggiato "Peri", and Istituto Tecnico "Pascal", Reggio Emilia, and Liceo Classico "Tassoni", Modena. The test allowed us to learn the most common interests and curiosities of the students about musical acoustics, and their average knowledge of wave phenomena. In particular the results clearly showed us that the curiosity about how musical instruments work is a strong motivation for the students to approach the scientific method, but often the topic is entirely neglected in the classrooms, or it is addressed in a very abstract or vague way.

2. Objectives and methods

Our main goal consists in stimulating the interest of young people in physics as a mean of creating models for the description of natural phenomena. At the same time we mean to provide teachers with a source of valuable materials for their everyday work. In particular we wish the user to be able to:

- easily and effectively visualize the wave phenomena both in the frequency and time domain
- use simple theoretical instruments and techniques for the analysis of experimental data
- use unifying wave concepts to interpret everyday observed acoustical phenomena

– connect elementary textbook concepts to realistic examples and applications

To obtain these objectives we have:

– inserted in the text a huge amount of visual and auditory clues, and programmed interactive applets
– made the range of conceptual links and hyper-links between the pages and topics as wide as possible
– exploited actual curiosities of students and users in general about real phenomena or devices to show the predictive and explicative power of physical concepts
– exploited the common widespread experience of people about sound and music to drive the user to a scientific approach to Nature

3. Structure

The website is located at the URL http://fisicaondemusica.unimore.it. It includes about 190 html pages in Italian, more than 1300 multimedia files, 3 multi-function Java applets. The entry page is an index for all the topics, that are grouped in four sections: “Wave physics”, “Sound and perception”, “Music and musical instruments”, “Formula and advanced sections”. Browsing is enhanced by means of special sections like the “Galleries” (a visual index for the whole site), “Questions and Answers” (collecting FAQ and curiosities), “Glossary” (explaining all the terms), and “Guided paths” (especially suited for high school teachers looking ready-to-use modules including our interactive simulations). All the materials created by the authors are distributed under a *Creative Commons* share-alike license. Three applets are available: *Wave2D*, *Fourier*, and J*Pipes*. The first two applets are inspired upon Paul Falstad's series (www.falstad.com). They have been perfected, and adapted to a broader range of physical situations, mainly preserving the original concept design, while the third applet was created entirely from scratch.

Wave2D is a virtual environment that includes a large number of setups for experimenting with wave phenomena in 2D. It can also be used to create user defined configurations, and it runs a real-time simulation of the wave dynamics of the system. It is not suitable for quantitative analysis yet, but it was proved to be very useful in enhancing the mental picture of wave phenomena beyond the stationary state, and in avoiding the simplified (and sometimes misleading) framework of optical rays. *Fourier* allows to experiment in real time with the spectral decomposition of sounds, granting the user the possibility of building and configuring his/her own stationary sound waves. *Pipes* is a completely new applet designed by the author, featuring the acoustic response of sound ducts. It allows the user to interactively modify the shape of a pipe, and to evaluate the changes in its theoretical acoustic impedance. It can be effectively used both as an easy to use design program for wind instruments, and as an investigation tool to get immediate, yet scientifically accurate quantitative information about the connections between linear response theory concepts, and the actual perceived musical sound.

The textual part of the site is organized in two interconnected levels: the elementary level is usually adopted in all of the entry pages of each subject. The pages in this level make little or no use of formulas, and short paragraphs are usually interleaved with a large number of pictures and animations. This level is particularly suited to those users that are interested in getting a better view of the addressed phenomena, but do not have a specific scientific culture. This level aims to provide an effective set of tools to get the most possible precise idea of the dynamics of each phenomenon, without going in too much quantitative details. The advanced level is usually reached via the links in the entry pages, and its purpose is to help users to get a better quantitative understanding of the topics. Some math is used, mostly at a high school level, and the role and of the most basic notions is always stressed, even when analyzing real-world complex phenomena. This level is particularly suited for students under the supervision of teachers looking for updates, new examples, and fresh ideas for their didactic activities. Finally the advanced sections collects useful formula, tables, data, and proof at graduate level mainly useful for teachers looking for a unified reference to sound and wave physics.

4. Conclusions

I outlined the main features of a web-based environment, that, by its very nature, cannot be fully understood resting on its textual description on the paper. The site has been used in interactive lessons and presentations about popular science topics, while its potential use in the classrooms was tested in an experimental program carried out in 2008 in the “Liceo Classico-Scientifico

Ariosto-Spallanzani", and "Liceo Scientifico Aldo Moro", Reggio Emilia (Rozzi 2009). The materials have been used in several courses for teachers (SISS) Italy wide.
The web site is being currently consulted by the members of several communities, including musicians, instrument makers, high school students and teachers, and university scholars. Their constant feedback, appreciation, and curiosity is a primary encouragement to continue the development. On-line from April 2008 it counts an average of 17000 hits (approximately corresponding to about 600 independent visits) per day. It is cited as a reference by Yahoo-Answers, Wikipedia, and several didactics forum on the net in the field of physics, acoustics, electronics, vibration engineering, music, etc. Future development include the translation to English, the extension to the instrument sections, and sections devoted to explore the links between classical wave theory and quantum physics.

Rozzi C A (2009), Proceedings of the conference "New Trends in Science and Education Technology", CLUEB, Bologna, in print