CHARACTERISTICS OF PRE-SERVICE TEACHER KNOWLEDGE OF MECHANICAL WAVE PROPAGATION: IMPLICATION FOR FRAMING ADEQUATE EDUCATION ENVIRONMENTS

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1 INTRODUCTION

Recent physics education research has been focused on a modelling perspective for designing classroom activities that enable pupils to learn about science as a modelling endeavour.

Modelling is intended as the process of constructing and using models [1] (http://modeling.asu.edu/; http://www.wcer.wisc.edu/NCISLA/MUSE/). Learning physics via model construction should, therefore, involve the development of modelling strategies making pupils able to figure out their own physical experiences and evaluate information reported by others.

Moreover, it has been pointed out [2, 3] that comprehension in a particular field of physics is attained when it is possible to predict a physical phenomenon from its physical model that can or can not include its mathematical representation. Learners have to be able to construct mental models, determining the perception of phenomena, whose predictions and explanations agree with those of the accepted physical model. Many research studies show that the learning of mathematical procedures in them cannot guarantee the physical understanding of phenomena [3]. The understanding of mathematical procedures needs to be linked to physical understanding.

On the other hand, some researches [3-5] pointed out that science teachers have often not been explicitly educated and trained in the modelling strategies and, consequently, they show difficulties in order to introduce and sustain a more authentic, model-based curriculum, and to guide students in their learning. The new demands that the requirements of modelling curricula place on teacher education must be explicitly addressed.

The present study is part of a Project aimed at redesigning and implementing laboratory courses of the Graduate Program for Physics Teacher Education at University of Palermo focused on improving Prospective Teachers' (PT) modelling abilities in physics. In particular, it refers at the improving modelling abilities in the field of mechanical wave propagation.

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2 EMPIRICAL STUDY

2.1 The characteristics of PTs' knowledge about mechanical waves

The study involved thirty-five PTs attending the laboratory course mechanical waves; they were graduated in physics or engineering or mathematics. Their physics knowledge has been evaluated through the results to the admission test, assessing the knowledge of the basic topics of physics. In particular, the majority of our PTs showed a good knowledge of basic concepts about mechanical wave propagation. In fact, more than 70% of PTs gave a satisfying definition of mechanical wave and showed a good knowledge of the mathematical definition of wave as well as of the physical meanings of the different parameters characterising a wave.

However, in analysing real phenomenological or experimental situations PTs showed to be unable to supply adequate descriptive as well as interpretative explanations, by providing qualitative models based on cause/effect relationships or explanatory hypotheses that introduce models and underlying mechanisms of functioning (see [6] for details of tests). As a relevant result for the laboratory design and organization, a high percentage of PTs showed to use qualitative models very similar to those displayed by high school students [6]. As for example, in order to explain the differences in mechanical wave (and sound in particular) speed in different media:

- many PTs assigned a fundamental role to the medium without specifying what kind of role;
- a relevant number of PTs thought that density of a medium determines the distance a molecule can move and then transfer sound;
- some PTs assigned to the medium the role of obstructing and slowing down sound propagation.

In synthesis, although PTs showed a good knowledge of mechanical wave concepts, they were not equipped with a deep knowledge of some significant factors which are considered relevant in influencing modelling learning, such as: to perform accurate observations of phenomena, to carefully plan experiments and to search for predictive explanations. These results guided us in designing and implementing the laboratory work.

2.2 The design of laboratory activities

Our design was mainly aimed at supplying PTs with pedagogical tools suitable to the purpose of conceptualising physics models and gaining the abilities connected with modelling procedures. This involved stimulating PTs in hands-on learning and metareflection through negotiation in collaborative inquiry.

As a starting point, PTs performed observations using materials easy to find (ropes, slinky,…) and analysis of videos concerning everyday phenomena involving wave propagation. PTs were stimulated in finding the involved physical variables, inferring their relationships and predicting behaviours. This phase was also aimed at pointing out connections between spontaneous models and everyday phenomena.

The successive two phases involved experimenting and modelling activities. We here report the activities concerning the propagation of mechanical waves in solids materials.

a) Experiments and data analysis Experiments use cheap and easily available materials and commercial sensors (with computer interfaces), for open-ended investigations. We describe, here, the experimental activity that had great success in stimulating PTs to reflect about the inner functioning processes behind the wave propagation in a solid. Experiments involving mechanical pulses propagating in a long rod have been performed by measuring the contact time τ between a metallic colliding body and a rod end (see Fig. 1). A voltage sensor detects a signal when a physical contact between the colliding body and the rod's end is established and maintained (more details are reported in [7]).

Figures 1 and 2 show a sketch of the experimental apparatus and a typical signal detected by the voltage sensor, respectively. The contact time, τ, is measured by the time interval corresponding to the constant part of the signal.

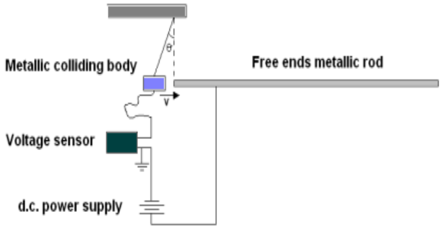

Figure 1 The apparatus to measure the contact time between two metallic colliding bodies.

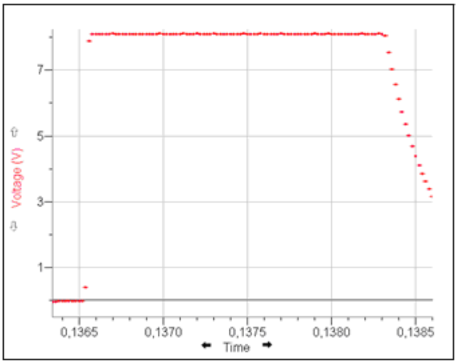

Figure 2 Experimental results for a brass rod of length L = 3 m and cross-sectional diameter d = 1 cm.

Measurements have been performed by using some cylindrical aluminium and brass rods of different lengths and cross-sections, in order to analyse the effect of different parameters (mass of the colliding body, length/section of the rod).

To answer the question: "do always colliding bodies stay in contact with the rod for all the time it takes to the pulse wave to go all along the rod and return back, regardless of their mass?" Another interesting experiment has been performed: measurement of contact times between rods and colliding bodies of different mass.

Figures 3a and 3b show that by using colliding bodies of mass equal to or greater than some values (named m^*), specific for brass and aluminium rods, all the detected τ values are almost constant, with mean values given by τ_{br} = (1.75 ± 0.02) $\cdot 10^{-3}$ s and τ_{al} = (1.20 ± 0.02) $\cdot 10^{-3}$ s. These time values are the ones expected for the wave pulses produced in the collision to travel along 3 m long brass and aluminium rods, respectively, and return to the rods' end initially struck, after being reflected at the free end.

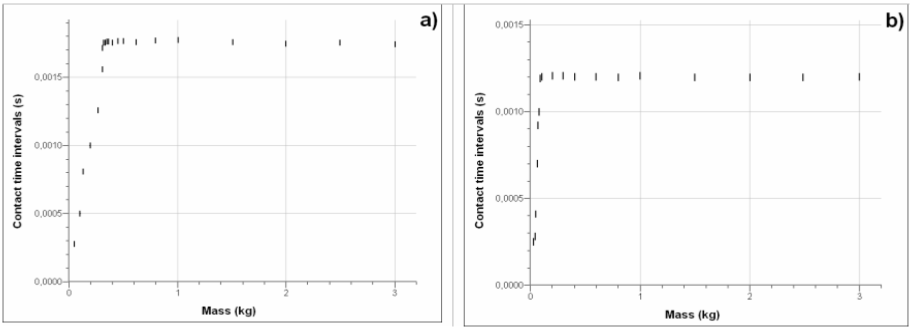

Figure 3 Plots of the measured contact times vs. the mass value of the colliding body in 3 m long brass (a) and aluminium (b) rods. Each point is the mean value of 10 measurements performed with the same colliding body mass. Error bars are the standard deviations of mean values.

The plots show that for low values of the colliding body mass the detected values of τ appear to be remarkably smaller than the aforementioned values. We can, then, infer the existence of 'minimal', m^*, values of the mass for which the colliding body remains in contact with the rods for all the pulse travelling time. If the colliding body mass is $m \geq m^*$, it can remain in contact with the left rod's end for the same time τ (see [7] for more details). If $m < m^*$, the colliding body bounces back after a shorter time interval.

b) Modelling After the analysis of experimental results, PTs were involved in activities aimed at building physical models able to describe and interpret observations and experiments.

A mesoscopic model of the rod, thought as a collection of spring-particle blocks, concentrating the elastic, *K,* and mass, μ, properties and interacting each other, has been build (see Fig. 4).

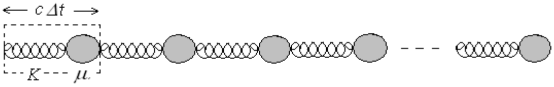

Figure 4 A concentrate parameter model of an elastic rod.

In order to visualize the dynamics of both rod and colliding body, the model has been implemented by using the simulation environment Interactive Physics (IP) (http://www.design-simulation.com/IP/index.php) (see Fig. 5). The simulation allows the user to modify the values of masses, the colliding body velocity and the chain elastic constants. Simulation results have been compared with the experimental data reported in Fig. 3.

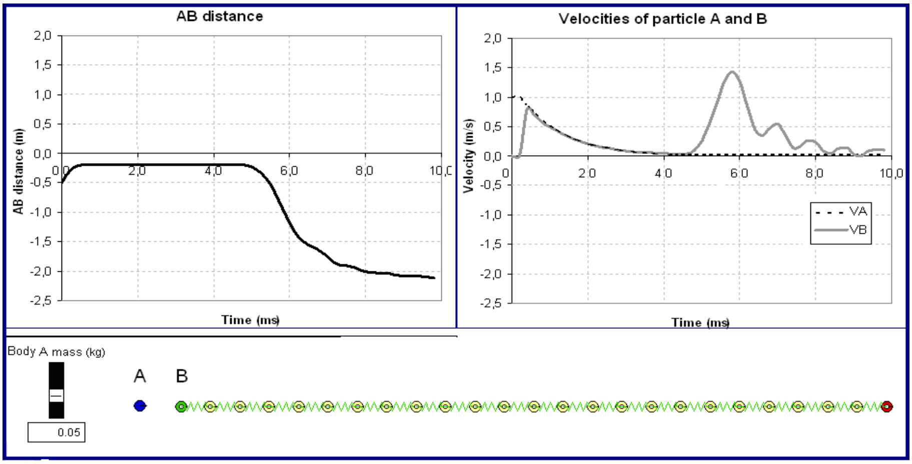

Figure 5 IP interface of the simulation: on the left, the relative distance between body A and particle B as functions of time; on the right, velocities of A (dashed line) and B (grey bold line) as functions of time. Contact time t is measured by the length of the plateau (on the left) that is equal to the distance between the two velocity peaks (on the right).

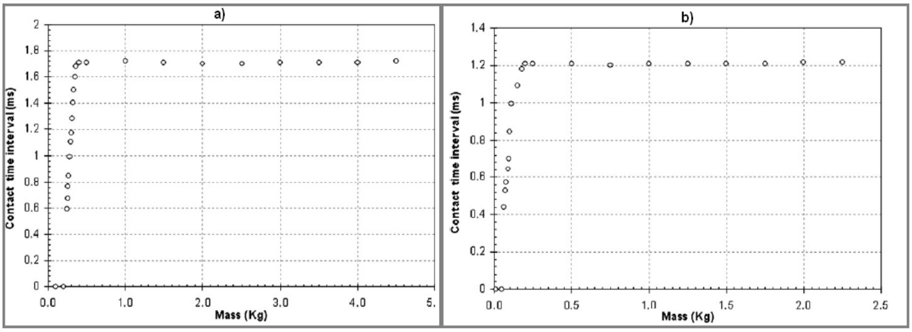

Figure 6 Contact time of particles A and B as a function of body A's mass, resulting from IP simulations in the case of 3 m long simulated (a) brass and (b) aluminium chains.

Fig. 6 shows a plot of contact time intervals, τ, between body A and particle B as a function of the colliding mass m for two chains modelling brass and aluminium by appropriately varying the elastic constant and mass values of the chain particles. The contact times appear to be constant for values of body A mass greater than a certain value, specific for each of the two "materials". These constant time values appear to be in accord with the time values a mechanical wave pulse should take to travel along the chain lengths and return back to the first chain particle. If lower mass A values are used, the contact times appear to be smaller.

3 CONCLUSIONS

In this paper, we present the design of a learning environment aimed at stimulating PTs to reflect about their mental models emerging from MWPT answer sheets and at gaining abilities connected with experimenting and modelling procedures.

The design characteristics were focused on stimulating modifications in PTs required disciplinary as well as pedagogical competencies and allow PTs to experience the same modelling based learning environments they are supposed to implement in their future classrooms. This approach showed a two-fold advantage: PTs could directly verify their pedagogical validity and, at the same time, make use of them to master the physics subject at the level of conceptual understanding that they will need to develop in their future students.

A detailed analysis of PTs' activities and produced materials is in progress. However, the observation of PTs' group work during lab and simulation sections allows us to conclude that PTs have modified their initial attitude to physics laboratory activities and modelling. Moreover, it was also evident an actual deepening of PTs understanding of the involved wave physics contents and their relations with the movement of a real elastic body.

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