Addressing undergraduate students' difficulty in learning the General Principle of Work and Mechanical Energy

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Abstract. In this contribution, we report the implementation and evaluation of a interactive Teaching Learning Sequence (TLS) introducing the concepts of Work, energy and the relations between them. The sequence has been designed with the Design Based Research (DBR) methodology. In order to analyse the effectiveness of the Sequence for students to be able to achieve the set learning goals, a pre-post test was designed. We was given the questionnaires, over two academic years (14/15 and 16/17), to about 170 students who attended the introductory physics course for the first engineering degree. Our findings show that the majority of experimental students progress from particular cases of the relation between work and energy towards an explanatory general principle of work and energy. We discuss implications of our findings in relation to the DBR methodology used to design the TLS.

1 Introduction and aims

One of the greatest challenges in physics teaching revolves around helping students to build scientific models that they can use to understand natural phenomena. The challenge is particularly serious for scientific areas where phenomena are complex and a large quantity of prior information has built up. A representative example of one of these areas in physics is the Generalized Principle of Work and Energy (GPWE) in Mechanics [1,2]. Consequently, the need arise to design, implement and evaluate Teaching-Learning Sequences that improve students understanding of the GPWE integrated in the curriculum. Although teaching and learning sequences are not the only factors that influence learning in classrooms, the improvement derived from the use of research–based TLS has been shown in some cases to be significant even for teachers with little specific training of the specific TLS [3,4].

This work describes a part of a sequence for teaching GPWE in the introductory physics course for the first engineering degree. In this study, we construct the sequence within the framework of a research and development process [1]. We present our design and evaluation process as an implementation of Design Based Research (from now on, "DBR") methodology [5]. Our study focuses on analyzing how a TLS designed on DBR methodology can improve students understanding on GPWE.

2 Methods

We designed a TLS following the phases of DBR methodology: a) Defining the learning goals taking into account context, curriculum, epistemology of Physics and previous studies; b) Construct the teaching material (activities, worksheets …); c) pre-post questionnaires for evaluation students procedural and conceptual learning [5].

The study was carried out at the University of the Basque Country over a two years period. All first-year Engineering students (about 170 experimental students and 115 control students) had previously completed two years of physics at high school. The data of learning evaluation were collected from pre and post written evaluation questionnaires of six open-ended questions. The aim was to obtain information on student reasoning trends in relation to the learning goals set in the sequence [6]. The research team members went on to analyse all questionnaires independently; the mean Kappa Cohen reliability coefficient was 0.87. Any differences in the categories were resolved through discussion.

3 Results

The Hake index between the pre-test and the post-test of the experimental group varies from 0.17 to 0.58 depending on the question in the course 2015/16 with a median of 0.39. During the course of 2016/17 an improvement was noted, with the variation of the index between 0.21 and 0.63 and with a median of 0.48. A Hake index greater than 0.10 indicates an improvement in learning. In addition, the comparison between the percentages of correct answers in the post-test between the experimental and control groups indicates that there are significant differences (χ^2) of better understanding of the objectives in the experimental students. A better learning is observed in the understanding of the concept of work and its relation with the variation of energy of the system. In addition, most experimental students know the limitations of the kinetic energy theorem, they define the system when applying the GPWE and, consequently, apply it correctly to a greater extent than the control students.

4 Discussion and conclusions

Our findings suggest that most students progress from an "everyday thinking" conception of work and energy characterised by its inconsistent reasoning and upheld by intuition, towards an explanatory model based on the Generalized Principle of Work and Energy that interpret mechanical work as a way of changing different types energy in a defined system that interact with the surrounding. We have found that the majority of students abandon reasoning based particular cases and they are capable of analysing the phenomena from a general principle. However, we found that in some learning indicators only a minority of students demonstrate adequate comprehension and we will have to discuss in deep some aspects of the TLS.

The main implication of our work that we would like to discuss is the importance and feasibility of approaching the design of the TLS following the DBR methodology. This methodology allows redesigning the TLS in accordance with the empirical data obtained in the implementation and evaluation. This is an important part of considering the design of teaching materials both, as a research process and as a product.

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