A Teaching – Learning Sequence Concerning Dynamic Interactions: The Need for Appropriate Software *

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Abstract. *In this study we describe the underlying principles we took into consideration in order to design a teaching-learning sequence to teach dynamic interactions to student - teachers. Specifically, we describe the pedagogical dimension, namely, students' basic conceptual difficulties in this subject, as they are derived from literature and an empirical research. Moreover, we refer to the epistemic dimension, namely the issues dealing with the didactical transformation of content to knowledge suitable for the specific target group. We particularly focus on the reasons that led us to design proper software to support teaching and learning.*

Keywords. Dynamic interaction**,** Newton's 3rd Law, software, teaching-learning sequence

1. Introduction

This research concerns the design, development and implementation of a teaching – learning sequence (TLS) for student - teachers. The core content of the TLS is the revealing of the concept of force as the measure of the strength of the interactions, in the context of the 3rd Newton's Law.

The design of our research program includes three phases: a) the elicitation and classification of student conceptions about dynamic interactions, as well as the study and analysis of the content of the corresponding subject matter b) the design of a TLS about teaching dynamic interactions for student – teachers c) the pilot and the main application of the TLS and its evaluation.

Many students meet difficulties in understanding the different topics of Physics. A common difficulty among topics is the creation or translation of the representations, as well as the comprehension or the use of mental models about a physical system. According to Christian and Belloni [1] computer simulations can help students to understand Physics in different ways, that is making sense of translation among representations or building mental models of physical systems. For this reason, we decided to exploit simulations' potentiality in the TLS in order to enable students to comprehend the concept of dynamic interaction. In literature, we can find a limited number of studies developing software regarding Newton's 3rd Law [2], in contrast with the big number of studies dealing with the 1st and 2nd Law [3].

In this paper, we focus on the need to design and implement proper software in order to teach a part of the TLS content. Specifically, the research question we are concerned about is: "Which are and why the underlying principles we need to develop software in order to teach dynamic interaction in the 3rd Newton Law context?"

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In another paper in this volume [4] the structure and the content of this software are explicitly described.

2. Research Design of the Teaching-Learning Sequence

2.1. Literature

TLSs are currently considered to be powerful tools for improving teaching and learning in Science. According to Meheut and Psillos [5] TLSs comprise small-scale curricula and their designing can be represented with the didactical rhombus, which is set up by two interacting dipoles. The first is the connection between scientific knowledge-material world (epistemic dimension) and the second is the connection between a teacher and his/her pupils (pedagogical dimension).

The pedagogical dimension is usually placed into a constructivist context. This fact points to the need to acknowledge the differences between the scientific view about the content and the alternative conceptions of pupils' target group. The epistemic dimension combined with the pedagogical one leads us to the didactical content transformation, namely, to knowledge suitable to be taught to a target group [6].

In literature, there is a big number of studies both on learners' problems to comprehend the concept of force and the ways to teach it. These studies ascertain that force constitutes one of the primary concepts children face in everyday life, while the corresponding conceptual models they develop are usually in contrast to the scientific ones [7, 8, 9, 10, 11].

With respect to the 3rd Newton's Law and the concepts of force and interaction, recent studies systematically deal with the differences between the alternative learners' conceptions and the scientific view. The results of these studies point to three general aspects of pupils' typical views of the force concept and the science to be taught. a) Students consider that force is an acquired (or innate) property of objects, while in science force is a measure of an interaction between two objects [12]. b) Students find it difficult to accept that an inert or an inanimate object can exert force, while the scientific view is that interaction always comes in pairs between two objects independently of the nature of the objects [12]. For example, Greek students (11-16 years old) believe that interaction exists only when motion exists. c) Students don't use the Newton's third law in every situation, while the notion of symmetrical interaction between two objects is applicable to all situations [2, 12]. E.g. in Australia, research results show that the majority of pupils recognize two forces between a spring and a book on the spring correctly, while they find it difficult to indicate forces between a table and a book on it [13]. In literature, the term contextual coherence is used to evaluate the extent pupils "can apply a concept or a physical principle in a variety of familiar and novel situations" [12].

2.2. Empirical Study

Taking into consideration the literature outcomes [14] and a few semi-structured interviews, we developed a questionnaire to study the 1st year students' conceptions about dynamic interactions in a number of Schools of Education in Greece. Specifically, we surveyed the conceptions of 260 first year teacher-students about the concept of dynamic interactions in three different contexts, namely, the gravitational, the magnetic and the electrostatic one. The questionnaire, which will be presented elsewhere [15], comprises ten questions. Three of them deal with gravitational interaction, four questions deal with the magnetic one, and the last three look into electrostatic interactions [15]. Each question has the same structure, including three sub-questions and drawings. In each question, there is a system of two inert objects (the only exception is the pair of Earth-Moon), which interact e.g, two inert wooden cubes, two charged bars, a magnet and an iron object e.t.c.

The results of our empirical study seem to be corresponded to the related literature results about pupils. Following, we refer only to those related the software development.

a) We ascertained that students support that interacting entities "give" rather, than exert force; namely, they perceive force as an innate property. This perception is symbolically expressed when they are asked to represent force by an arrow. Students place the arrow on the object, which exerts the force.

b) Students seem to perceive the dynamic interaction between inert magnets and inert charged objects easier than the one between inert bodies. Specifically, between two charged bars or between two magnets, they recognize that the objects exert force on each other. With respect to the gravitational forces, the students recognize the interaction between celestial bodies (Earth-

Moon) easier than between celestial-terrestrial ones (Earth-apple) and between terrestrial ones (two inert wooden cubes). We interpret this as a lack of contextual coherence [16].

c) A limited number of students support the scientific view that the magnitude of the forces each body exerts to the other are equal. On the other hand, many students have a strong idea that the bigger the entity the greater the force exerted while they are interacting. For example, Earth exerts a bigger force to the Moon because it has bigger mass. A bigger magnet exerts bigger force to a smaller one, e.t.c.

3. The need for appropriate software

3.1. Epistemic and Pedagogical Principles

The basic principles for developing the TLS will arise from combining the two dimensions (epistemic and pedagogical) we described earlier. Namely, from a) the literature review results and from our empirical research on learners' alternative conceptions (pedagogical dimension) we analytically referred to and b) choosing the proper content, so that trans – phenomenological approach of the dynamic interactions (epistemic dimension) will be promoted.

The aim of the present TLS is to enable students to acquire a unified perception about dynamic interaction in three different contexts, which are the gravitational, the electrostatic and the magnetic one, using each time the corresponding entities, namely, mass, charge and magnets. This way, the trans – phenomenological character of interactions is revealed [17] and splitting of knowledge is avoided. The general aspect we want students to acquire, applying the TLS is: when entity A acts on entity B, simultaneously entity B acts on entity A. The interaction between them has the same magnitude and can be either attractive or repulsive.

3.2. Designing appropriate software

Based on the principles described earlier, we decided to develop software a) to cover a wide range of dynamic interaction application contexts b) to take into account the three general aspects of students' conceptions about force, interaction and the 3rd Newton's Law and c) to bear an interactive, still guided teaching - learning character.

The trans - phenomenological approach of dynamic interactions becomes especially difficult when designing lab exercises, since it is hard to pick up real objects or observable things in order to help students construct their own knowledge [18]. Actually, if we compare the three dynamic interactions – the gravitational, the electrostatic and the magnetic one – we ascertain that studying the two first with real objects and observable things is particularly difficult compared to the magnetic one. How is it possible for students to observe the gravitational interaction between two inert bodies and even the Earth – Moon interaction? Regarding electrostatic interaction, it often becomes difficult for the objects to attain or sustain charge for some time. Additionally, it is impossible for the students to carry out activities and know the charge of two different bodies both quickly and accurately. On the other hand, using magnets to study the interaction between them is rather simple.

Therefore, we decided to design software, which would include gravitational and electrostatic interactions in various cases either classic (the Earth – Moon effect) or novel (the effect of a big charged sphere on a small one, equally charged, in an imaginary situation). The very nature of the software allows us to use various situations, either real or simulated ones. E.g., we can study the action of a "space watermelon" on Earth or the action of a watermelon on an apple in a room or on the beach. We assume that students' practice in the lab in two distinctive contexts can actually help them acquire contextual coherence. This speculation has led us to the development of two units regarding the software. The first comprises five labs about gravitational interaction and the second one includes six labs about electrostatic interaction [4]. We decided that magnetic interactions would be studied with real lab work, similar to the activities students carry out in the other two contexts.

The outcomes of the literature and our empirical research prove that the three general aspects of pupils' conceptions are widely spread among learners and it can be very hard to change them to the scientifically accepted ones (see above). That's the reason we decided to include features of these aspects in every lab exercise of the software and present them in the same pattern so that the students can easier conceive them.

Specifically, in the 1st step of each activity we negotiate the general aspect that force is an innate property. We ask students to depict the action of an entity (entity A) on another one (entity B) with an arrow and then check if they have placed the arrow correctly. Thus, the students have the chance to speculate in various cases both on their view that an entity "gives" force than exerts force on another one and the way they depict this action. In the 2nd step of each exercise we focus on the concept of mutuality. We ask students to draw the arrow that shows the action of the second entity (entity B) on the first one (entity A). In this way, students have the chance to find out that in every case forces are exerted from both entities. Moreover, except the Earth-Moon case, the entities are always inert. In the 3rd step of the exercises, we ask students to check the magnitudes of the forces. That is, to predict and check if the magnitudes of the actions each entity exerts on the other are equal (aspect c). In the last step of each exercise, we thought it would be important to persist on the concept of mutuality that characterizes every dynamic interaction (aspects a-c). Specifically, students can remove or get the two entities closer to each other (e.g., an apple and a watermelon on the beach) and observe that the two arrows change in magnitude simultaneously and always pointing one against the other.

The use of the software has the advantage of the pedagogical dimension compared to the real lab, since it can include a substantial number of different alternative conceptions in its context. We studied the students' answers of our empirical research, we sorted them out and we placed them among the software context. Thus, the students, while talking in their group, had the ability to check various parameters in the software, as well as to compare their own answers with their colleagues' ones. For example students checked the magnitude of interactive forces between two entities with unequal mass and equal charges, or equal mass, equal and unequal charges, e.t.c.

4.Discussion

In this study we focus on the development of the software designed for an innovative 10-hour TLS. This software was designed to support the first three lessons of the TLS. During the software application discussions between the teacher and the students, teacher's recommendations and some classical experiments (magnetic dynamic interactions) occurred.

In the pilot phase, we implemented the TLS in two groups of 8 primary student – teachers and 8 pre-school student – teachers. The initial results show that the students have easily overcome some of their conceptual difficulties. This was the case when they were confronting the «give force» model. After the first 2-3 activities, it seems that the students overcome it placing force on the body it is exerted to, instead of the body exerting it. With respect to other aspects, change was not so easy. E.g., students found difficult to understand why the magnitudes of interacting forces are equal, though the size of the interacting entities are not. This problem seemed to be overcome when we mathematically introduced the law of the inverse square. The students saw that the magnitudes of both entities contribute to the formation of the magnitude of each force.

Generally, from the pilot application results, it seems that the software contributes to students' overcoming difficulties. Nevertheless, "it does not make sense, to ask about the effectiveness of lab work in general" but "we need to ask about the effectiveness of specific lab work tasks for achieving specific learning objectives" [18]. The learning objectives in our software are divided in two categories: the content and the process [18]. In the first category of the learning outcomes (content) our aim is to help students to understand the concept of dynamic interaction, across different contexts. That means to understand that two entities interact mutually and the strength of interaction is the same independently of the amount of entities (mass or charge). In the second category of the learning outcomes (process) our aim is to help students to understand the process of scientific representation of interaction. This means that each action of the interaction is represented with an arrow, which has a specific point it is applied on and a specific direction.

At the beginning of this paper, we mentioned that we transformed the content to make it suitable for our target group. This fact sets some limits to the epistemic dimension of the software. Specifically, in the software we introduced only inert entities, which interacted from a distance. We did not discuss the interaction of entities in motion or in touch.

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