

Basic Concepts of Special Theory of Relativity in Secondary Education: Do students understand them?*

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Introduction

The Theory of Special Relativity (SR) is one of the foundations of Modern Physics. Many investigations have been carried out on how it can be approached by university students (Pietrocola and Zylbersztajn 1999, Scherr 2001, etc); whereas similar investigations in Secondary Education (S.E.) are limited. To teach SR, it is necessary to introduce students to the key-concepts of Relativity.

As Villani and Arruda (1998) maintain, the teaching of Relativity in S.E. aims at students' awareness of the conceptual rupture between Newtonian and modern Physics. In order to achieve this, it is important to know the students' ideas, as well as the difficulties they encounter in approaching the relevant concepts. Furthermore, to achieve conceptual change and to construct their own knowledge, students need to solve complex problems; think about their ideas; listen to the ideas of others; thus assuming control of their learning (Vosniadou et al. 2001).

The research focuses on concepts considered prerequisites for the understanding of the SR, and aims at the investigation of:

- A) the students' difficulties in the concepts referring to:
 - the relativity of motion,
 - the maximum speed in nature
- B) the ways promoting conceptual change in these concepts.

Methods and Sample

The research instrument was a questionnaire consisting of four short stories. Each was based on a scenario concerning snapshots of everyday life. The persons involved in these stories supported alternative positions about the investigating concepts. Students were asked to express their ideas and provide appropriate arguments supporting them. The first three stories investigated the relativity of motion and the fourth, the possibility of a maximum speed existing in nature. The construction of the questionnaire was such that each of the three first short stories was built on an increasing complexity. The questions were based on the difficulties students face in these concepts according to bibliography. (Panse et al. 1994, Scherr 2001, Villani and Pacca 1987).

The sample was 124 students of upper S.E. (10th, 11th and 12th grades, aged 15-17). The students came from two secondary schools: one in Athens (the school associated with the Department of Education of the University of Athens), and the other on Samos (an island on the eastern borders of Greece).

The research was carried out in three phases.

The questionnaire was addressed to:

- A) 114 students individually.
- B) Ten students of 12th grade, who have chosen Science as their main subject, divided into two groups. Members of each group had to argue and decide the proper answer to the questions. The relevant discourse of the two groups was recorded, to register the arguments developed and the difficulties they face. According to Scherr (2001), such procedure makes students think aloud and articulate the reasoning they use to arrive at their responses.
- C) i. Five students (10th grade) were chosen among these students who had already answered the questionnaire. The criterion of their choice was the variety of ideas and the elaboration of the various arguments aimed to support their ideas, expressed in the first phase of the

research. They were asked to discuss and argue about the positions provided in the stories. Their discussion was also recorded, to investigate whether they could change their ideas when confronting the argumentations of the others.

ii. Four months later, a similar questionnaire was addressed to these five students in order to check if there was any conceptual change. The concepts were the same but the context was slightly different.

The analysis of the collected data was based on the content analysis (questionnaires) and on the discourse analysis (cassette recordings) which afforded micro analytic descriptions of students' discourse (Duit 1997). The criterion of the above analysis was the recording of the students' ideas about the relevant phenomena and the kind of arguments they used.

Findings

A) The content analysis (1st phase) showed that students meet difficulties in grasping the relativity of motion and in using the frames of reference properly. Students' ability to use frames of reference as conceptual instruments in handling the relativity of motion decreases with the complexity of the conceptual load, which the elaboration of the story demands. Interesting is the fact that in the first short story, which is the simplest, 21% of the students use the frames of reference, whereas in the second short story the percentage is decreased to 9% and in the third to 6%. They consider as "objective observer" either the stationary one, or the one who performs the prime action of the story. The answers of the majority of the students are mainly determined by their everyday experience and by common sense. They use tautologies and some students tried to represent the motions which were described in the stories to answer.

Furthermore, their answers to the fourth story reveal that most of the students believe that surpassing the speed of light is a technological matter.

Between the two schools and among the different grades, there was no statistical semantic difference. (The questions were open so the analysis is qualitative).

B) The discourse analysis (2nd phase) showed that although the students refer to the concept of the frame of reference, they have difficulties in applying it especially in complex environments (e.g. when the problem demands the change of frame of reference). In many cases, their argumentations are characterized by their daily experience and by common sense too. In the fourth question about maximum speed in nature, the first group supported the idea that in the future the speed of light will be surpassed, whereas the second group couldn't come to a conclusion.

C) i. The discourse analysis (3rd phase) reveals the potential of the discourse among students. Thus, whereas initially three students out of five supported wrong ideas; finally the group moved to the correct ones. To this result, the role of one of the first two students seemed important; although he had a low profile, he had effect on the other students being based on his ability to use strong arguments. In the short story concerning maximum speed, they didn't come to a conclusion, because they were influenced by science fiction and they digressed.

ii. The content analysis of the questionnaire four months later reveals that:

All the answers concerning the relativity of motion were correct. They all seem to have realized that in order to specify if something is moving we have to determine the frame of reference. But, they didn't seem to be able to answer the question about the speed of light. Only one student gave the correct answer. An interesting point is that all students supported that the speed of light is the maximum, when they were asked directly, but they couldn't apply it to the problem.

Conclusions and Implications

Students seem to face difficulties in dealing with relativity of motion (as Villani and Pacca, 1987, also mention in their research), in using frames of reference (as it is commended by Panse et al, 1994) and in realizing that the maximum speed in nature is the speed of light which is an intrinsic property of nature. Discussion seems to play an important role in negotiating their ideas, which indicates a possible contribution towards the conceptual change. Worth noticing is the fact that students had the opportunity (third phase) to reexamine the subject again. In this phase, the synthesis of the group is important (mixed ideas), which makes the first phase (the investigation of ideas) essential. The increasing complexity of the questions proved to be positive too, because students had the opportunity to think deeply on the subject and to elaborate their ideas in more complex situations. This is very important, because it reveals students' implicit conceptions, thus assisting them to understand complex subject matter, such as S.T.R. (Hewson 1982).

Also, the students seem to prefer to handle problems in a mechanistic mathematical way, rather than in a qualitative physical way.

Informal sources of learning like popularized science books and science fiction seem to play a role; in some cases positive, and in others negative (as Bucchi, 1996, also mentions). They could think deeper and develop their way of thinking.

Undoubtedly, in order to teach Relativity in secondary school, it is essential to introduce key concepts like frames of reference and the speed of light. After this investigation, we can presume that we can deal with these subjects up to a point, since students seem to understand them and they attract their attention.

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* The research has been funded by the University of Athens

† Scholar of State Scholarships Foundation