Relativity of the simultaneity in high school: an analysis based on the Theory of the Conceptual Fields

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Abstract. *We present results related to the conceptualization of the relativity of simultaneity in the secondary school, adopting the Theory of Conceptual fields. Four implementations were carried out in four 11-year courses (15-16 years old students) in a public school in Colombia (N = 128). We analyze the results obtained for two didactic situations that approach the relativity of simultaneity from the relativistic postulates. The results indicate that the situations analysed would produce the emergence and awareness of Operational Invariants rooted to Galileo's relativity, which would help to conceptualise the relativity of simultaneity in secondary school.*

1 Introduction

It is a known that the Special Theory of Relativity (STR) is not generally taught in High School (HS). The reasons for this are as diverse as complex, such as the lack of appropriate didactic devices for teachers to teach STR in HS, and the way in which school physics is taught, which does not allow conceptualizing the basic concepts of neither, classical nor relativistic kinematics. There are few available investigations on the subject in HS [1-3], most focus on the errors of students at all levels, disregarding the genetic and pragmatic aspects of the conceptualization of complex notions such as those involved in both classical and relativistic kinematics. This work integrates a research project that intends to design a didactic sequence to teach the fundamental notions of the TER in lower and upper HS and to study its conceptualization adopting a developmental and pragmatic framework based on the TCF [4, 5]. Here we focus on the relativity of simultaneity.The study on10th grade students in Greece shows that for the students the simultaneity is absolute and independent of relative motion [6]. HS students have a pre-Galilean view of the motion, which consider to be absolute [6, 7]. These ideas survive the school teaching of classical kinematics, and when attempts are made to teach relativistic kinematics, students are expected to become aware of the conceptual break between Galilean and modern physics [8]. But how can they do so without the prior genesis of the relevant classical concepts?

There are no precedents in the literature of a didactic sequence for HS designed within the reference of the TCF, nor of the analysis of the conceptualization of basic concepts of the STR using this framework. To teach the STR and describe the process of conceptualizing its basic notions in secondary school, we have designed a didactic sequence based on what students know and not what they should know [9]. The successive versions of the sequence that we have developed are based on the implementations carried out in eight ES courses in Argentina and Colombia [10-12]. Here, we present results obtained in two situations of the previously mentioned sequence, which would allow students to arrive at the relativity of simultaneity. An inductive categorization is constructed from 256 protocols obtained during the exploratory implementation of the didactic sequence in four 11th grade courses (15-16 years) (N = 128) in a public school in Colombia. The categorization attempts to identify, describe and analyze the different ways of solving students and the underlying operative invariants, with the aim of testing whether the

situations designed produce the emergence and awareness of operative invariants linked to the Galilean relativity that allow arrive at the relativity of simultaneity in secondary school.

2 The two situations that are analyzed in this work

In the first situation S1, two rubber balls are shot at the same time and in opposite directions from the middle of an isolated wagon, which moves uniformly respect to the platform. The question is whether the balls come simultaneously or not to the walls at both ends of the wagon, for a fixed observer inside (middle) the wagon and another fixed on the platform. In the second situation S2 we replace the balls by light beams (laser). After predicting without calculations, students should respond using the corresponding relative velocities and the relativity principle and solving the meeting problems between projectiles and light beams with wagon walls, for both observers.

3 Conclusion

The results show the relevance of the operational invariants in the information gathering and the inferences made by the students and the complexity of the conceptualization process. The analysis shows some promising results about how students can use the addition of velocities appropriately. This type of tasks should be carried out in the teaching of classical kinematics, allowing the students to consider addition cases that are not habitual in their daily life, but that could apparently be treated by proposing the appropriate situations. The situations would contribute to the awareness that the second postulate of c-invariance eliminates any possibility of simultaneity "conservation", generating the difference of time when the beams of light are considered. The results suggest that the use of situations aimed at explaining and becoming aware of the absolute role of simultaneity in daily experience, pave the way for understanding the relativity of simultaneity.

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