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MAGNETIC FIELD AS PSEUDOVECTOR ENTITY IN PHYSICS EDUCATION

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Abstract

The analysis of the nature of the magnetic field offers the ideal framework in which students could address the mutual integration between mathematics and physical aspects facing experimentally the analysis of the phenomenology. Took look how students face experiments in which the phenomenology founds the theory and the mathematics offers its formalism as the best language to describe the explored phenomena, an activity concerning the pseudovectorial nature of the magnetic field was performed looking at the way in which the students' reasoning evolve.

1. Introduction

As in several physics situations, the knowledge of the symmetries of the physical systems analyzes the situations in a more effective and simple way, but the individuation of the symmetries could not be done without passing through the knowledge of the laws of transformation of the single entities that take part in the systems (Foot & Volkas, 1995; Kozlov & Valerij, 1995; Mohapatra & Senjanovi´c, 1981; Redlich, 1984). For instance, symmetries are related with laws of conservation through the use of the Neother's first theorem (Noether et al 1918).

Unfortunately the role of symmetries in high school physics education is often underestimated. The ways in which entities are transformed by symmetry operations are usually not explicitly adressed, the usual goals of the high school physics courses are only aimed to the definition of the structures of the entities, and this approach creates an intellectual gap between students' studies in high school and university courses (Kolecki, 2002).

The main example of this intellectual gap is related to the distinction of axial and polar vectors. In high school this distinction is usually neglected and this learning knot lies submersed until students had to face it in the university courses.

This research is aimed to study how high school students' reasoning evolves in the construction of formal thinking when they face an explicit situation in which the pseudovectorial nature of the magnetic field is highlighted.

2. Context and Sample

Research work was done in the context of the Summer School of Modern Physics held in Udine during the summer of the 2011. The students participating to this school were the best 42 students coming from the last two years of the Italian high school (students are 17-18 years old; school grades 12^{th}-13^{th}). The opening course of this intensive school was the course of electromagnetism. It was a 16 hours long course distributed on 3 days.

3. Instruments and Methods

During this course of electromagnetism, students, divided in 7 groups of 6 components each one (4 groups of 12^{th} grade students and 3 of 13^{th} grade), follow an inquired based learning path that was constructed on the experimental exploration of the formal properties of the magnetic field with the aim to construct a formal representation of it. In particular the works on the exploration of the pseudovectorial properties of magnetic field was proposed in this learning path as an interactive lecture demonstration using an inquired based tutorial constructed with the Prevision-Experiment-Comparison (PEC) strategy (R. Martongelli, 2000; Michelini 2004).

The situation proposed was the one represented in Figure 1. Taking into account the given circuit, students had to draw its mirrored image representing the needles of the compass, the needle of the

reflected compass and analyze the picture (the compass is represented as the circle placed above the coils).

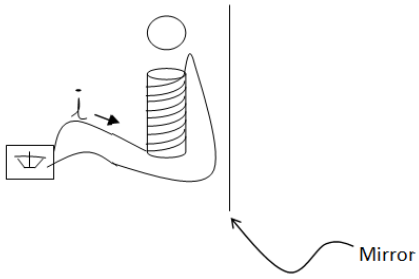


Figure 1: Situation proposed to the students in the first step

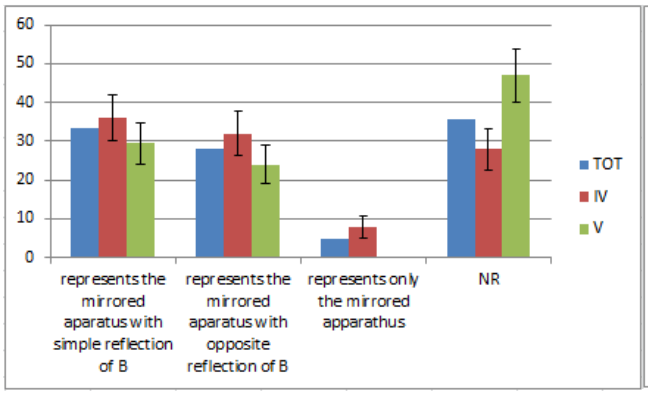
The second step was the realization of the experiment and the analysis of the original and the mirrored situations. Then, in the third part was asked to the students to rise up some considerations starting from the experimental observations.

4. Data

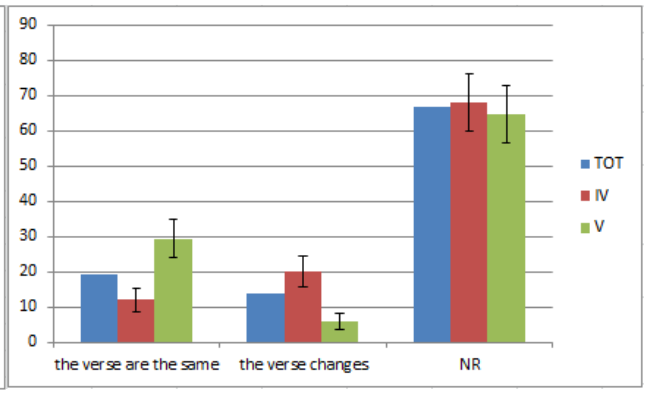
Data were collected using personal inquired based worksheets. In the first phase, the provisional phase, 36% of the students represent the mirrored image of the needle as simple reflection, 28% represents the needle of the compass with opposite verse, 5% represent only the mirrored apparatus and 36% did not replay to this task (Graph 1).

At the second phase, 19% of the students highlighted that the verse of the mirrored image of the needle is the same without justify it, while 14% highlights that the verse is different justifying their answers saying that the verse is different due to the right hand rule (2%), because the verse of rotation of the coils change (2%), because there is a change in the direction of the magnetic field (Graph 2).

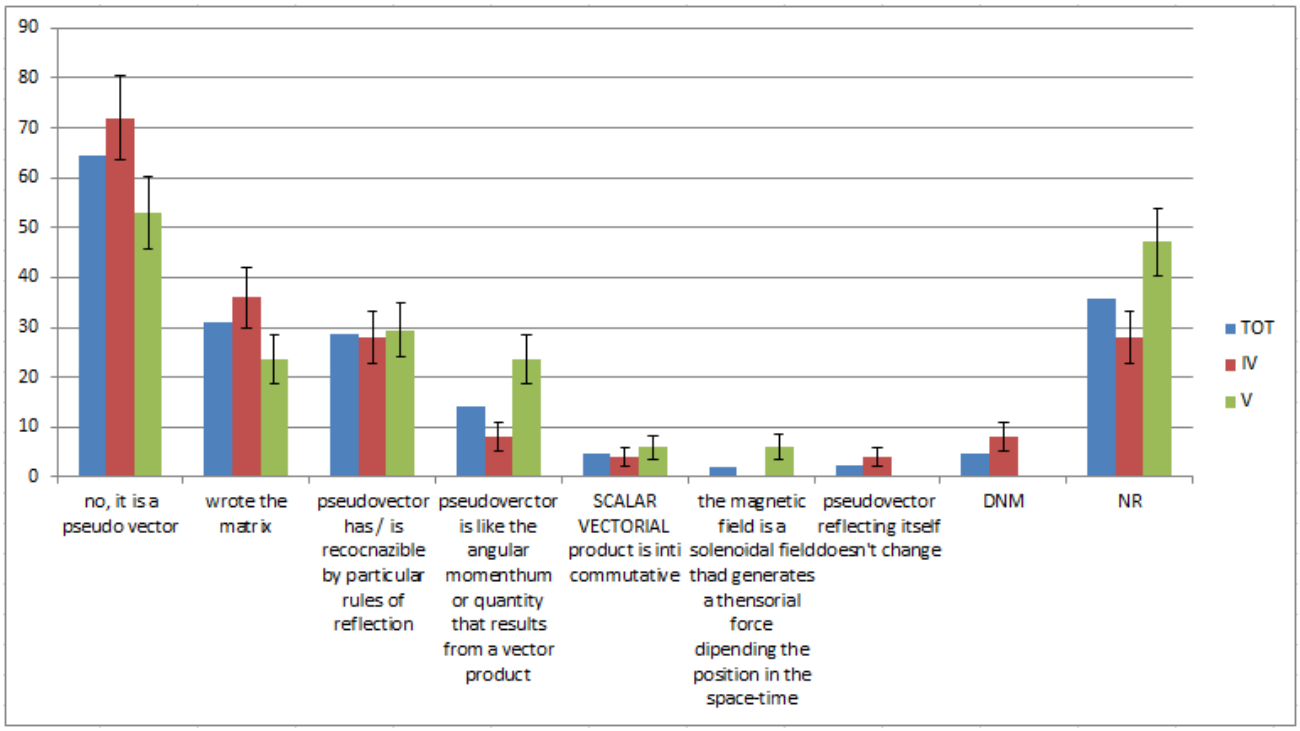
In phase three, 64% of the student highlight that the magnetic field is not a vector reporting only the representative matrix wrote by the teacher on the blackboard 31%, highlighting the rule in the recognition of the nature by the different rule of reflection 29%, pseudo magnetic vector is like the angular momentum or quantities that are defined through a vector product, 14% because the scalar product is anti-commutative 5%, or give other argumentation 4%, 5% did not motivate and the remaining 36% did not reply (Graph 3).



Graph 1: Representation of the mirrored image of the needle done by the students



Graph 2: Observation done by the students of the experimental results



Graph 3: Consideration done by the students on the nature of vector of the magnetic field

5. Data analysis

Neglecting the students who did not replay and the ones that represented only the mirrored apparatus, students' spontaneous approaches to the analysis of the mirrored situation are almost distributed equally on two different way of analysis: the first one is the representation of the needle of the compass as a simple reflection of it and the other is the drawing of the compass needle starting from physical consideration of the mirrored apparatus. No significant differences were highlighted between the 13th and 12th grade students.

In phase two, the analysis of the experimental situation, could be noticed how decrease the number of students that thought that the compass needle (i.e. the magnetic field) is reflected in the standard way, but not to a negligible percentage highlighting two main approaches. The first approach followed, by that the students of 13th grade (that had already faced the magnetic field description during the previous school year), is to look at the experiment as a confirmation of their ideas and not as an investigation opened to new findings, do not allowing them to notice keys elements that are in opposite with their thesis. The second approach, followed mainly by the 12th grade students is more open to the acceptance of eventually discording results respect to their prevision and so they can noticed and highlighted these discrepancies.

After the discussion, in the third phase, no one of the students recognize the magnetic field as a 'standard' vector, but the motivations that they gave are distributed on a wide spectrum that is reported in graph 3. Interesting to be noticed is that, even almost one third of the students justified this aspect reporting only the formal structure wrote on the blackboard by the teacher, the remaining part highlights experimental evidences to support this inference. In addition the data also highlight how mainly the 13th grade students propose comparisons and analogies with other quantities that they had already faced during their previous study (as for instance the angular momentum).

6. Conclusions and further remarks

This experimentation, done on the introduction to high school students of the nature of pseudovector of the magnetic field, highlight how through a simple experiment student could face this formal characteristic, recognize it and do comparison between this characteristic and analogous previous physic entity that they already know. In addition, looking data concerning question two, were highlighted how the standard way of teaching used in the high school represent an obstacle to the acceptation of this 'new' property by the student in they further studies.

References

Foot R, Volkas RR, Neutrino physics and the mirror world: How exact parity symmetry explains the solar neutrino deficit, the atmospheric neutrino anomaly, and the LSND experiment, Phys. Rev. D 52, 6595–6606 (1995).

Kolecki JC, An Introduction to Tensors for Students of Physics and Engineering, Tech. report, NASA Glenn Research Center, Cleveland, September (2002).

Kozlov, Valerij V, Symmetries, topology and resonances in Hamiltonian mechanics, (Book) Berlin, Germany: Springer-Verlag, Inc , 1995.

Martongelli R, Michelini M, Santi L, Stefanel A, Educational Proposals using New Technologies and Telematic Net for Physics, in Physics Teacher Education Beyond, 2000

Michelini, M, R Ragazzon, L. Santi, A. Stefanel (2004), "Implementing a formative module on quantum physics for pre-service teacher training", in M. Michelini (ed.), Quality Development in the Teacher Education and Training, Girep Book of Selected Papers, Udine, Forum, pp. 429-435.

Mohapatra R N, Senjanovi´c G, Neutrino masses and mixings in gauge models with spontaneous parity violation, Phys. Rev. D 23 (1981) 165.

Noether E, Invariante Variationsprobleme. Nachr. D. König. Gesellsch. D. Wiss. Zu Göttingen, Math-phys. Klasse 1918: 235–257, (1918).

Redlich A N, Parity violation and gauge non-invariance of the effective gauge field action in three dimensions, Phys. Rev. D 29 2366 (1984).