Introduction of observer dependent concepts into physics teaching of middle school

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Abstract. Physics curriculum of middle school and high school avoids dealing with the concept of observer (frame of reference). This tradition apparently draws on the assumption that students are incapable of learning observer dependent concepts because that requires an account with multiple answers valid for different observers. We empirically checked this convention and discovered that 9th grade students succeeded in applying frame of reference dependence to their accounts of daily experiences. In particular, they were able to construct graphs expressing dependence of displacement, distance, and velocity on time in the perspective of different inertial frames of references.

1. Theoretical Background

The concept of observer is one of the most fundamental and important both in classical and modern physics. Galileo's principle of relativity is in the foundation of classical mechanics and remains in modern relativistic theories. Such physics topics as equivalence principle, inertial forces, and concept definitions all involve observer dependence as an essential aspect. Basic kinematic concepts, location, velocity and acceleration are all observer dependent and science instruction cannot afford ignoring that. Yet, the adopted curricula often avoid dealing with this aspect [1]. Middle school curriculum adopted in our country totally excluded observer dependence, and it is barely mentioned in high school. The issue is considered to be as a sort of advanced subject matter to be treated at higher education level. Practically, this implies an assumption that students of middle school are incapable of learning observer based concepts as requiring dialectical (many faceted) account. This approach of single perspective was associated with the disciplinary knowledge of physical theories [2]. One may imagine that presentation of concepts as observer-dependent is pedagogically more demanding. Yet, these cognitive and pedagogical claims of curricular limitation could be a subject of research based testing, given the great conceptual advantage of inclusion observer-dependence into science curriculum, thus creating an adequate image of scientific knowledge.

2. Goals

Our experimental study includes two main operative goals: a) checking the ability of middle school students to learn observer-dependent concepts and handle their application; b) constructing and testing the efficiency of observer-dependence integrated teaching.

3. Methodology

Our research has lasted three years and included 8th and 9th grade students (N=16, N=117 respectively). The activities included: i) Pre-test which probed students' ability to analyze some situations considered from different points of view, students' intuition in that respect and their "body knowledge" of certain situations; ii) 15 lessons in which the students learned concepts in the domains of kinematics, forces, weight and gravitation (The research groups learned certain concepts as observer-dependent, whereas the students of the control groups learned the same concepts in the traditional way, avoiding dealing with their observer dependent nature); iii) First post-test in the experimental teaching group to evaluate their knowledge and skills regarding the concept of observer (goal a); iv) Second post-test to both

groups - in order to evaluate their knowledge and skills in comparison (goal b). This test drew solely on the subject matter from the traditional curriculum.

4. Findings and Conclusions

Our research findings clearly illustrate the positive impact of integrating the concept of observer in middle school science teaching, as they includes the following features: a) 9th grade students clearly showed their capability of understanding and applying observer-dependent concepts as in physical situations considered in a regular curriculum; b) 9th grade students succeeded in producing graphical dependence of displacement, distance, and velocity as a function of time in different frames of references; c) Learning kinematical concepts as observer-dependent actually enhances students' understanding of the considered concept; d) 9th grade students were clearly successful in drawing a force diagrams with respect to inertial and non-inertial frames of references; e) 9th grade students can successfully handle complementary definitions of weight, theoretical and operational; f) Students who learned the curriculum contents integrated with observer dependent concepts outscored the students that learned in the traditional way; g) Teaching the concept of observer and observe dependence significantly helped the students in achieving more mature and genuine conceptual knowledge of classical mechanics.

The positive impact of the experimental teaching calls to reexamine some aspects of the traditional teaching and current curriculum of middle school. It raises suggestions and posabilities as follows:

a) Dealing with the already included observer-dependent concepts in kinematics (location, trajectory, displacement, velocity) while practically considering them as such in formal account (graphs, alternative algebraic forms).
b) Dealing with the already included observer-dependent concepts in dynamics (kinetic and potential energies, forces). Including the operational definition of force and making legitimate inertial forces instead of considering them as a misconception of force-motion relationship [2].
c) More careful attitude to students' intuition based on sense experience, which should be considered in each specific case since it is not always misleading [3]. Inclusion of in parallel considering physics problem in non-inertial frame of reference, as well as in inertial one.
d) Explaining students' intuition, revealing students' initial ideas related to their "body knowledge" [4] in actual teaching relating them to the account in different frames of reference. Promoting the goal understanding as *refinement* instead of *replacing* [5].

We believe that our study indicates that using the suggested curricular and teaching changes matches the constructivist pedagogy in physics education, known for its great appealing power and good results.

References

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