Children' Ideas about Gravitation, Investigating a Model of Gravitational Field

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Abstract

From disciplinary, conceptual and common sense's knots pointed out in the literature, we have considered some key points such as the concept of action at a distance, the role of field lines, the trajectory of an object moving in a field and the field concept as a physical entity. The ideas of support and connection (medium) are related to the concept of action at a distance; field lines are usually identified with trajectories, while field concept is constructed in a lot of different ways, most often associating it to a sphere of force action.

To understand the role of the context in constructing the connection between everyday experience and scientific knowledge, children's (age from 5 to 9) spontaneous ideas have been explored as a game in an informal context of scientific culture dissemination. Reflections upon body falling and gravitational force were proposed by Rogers' interviews and drawings, investigating the role of a material model of the gravitational field. The model helps the interpretative prediction of resting and moving objects behavior in the part of the field represented. We propose it as a connection between local vision of earth gravitation and the vision related to gravitational properties of masses interacting with one another.

1 Introduction

It's well known that scientific education is based on commonsense ideas, constructed by interacting with the world [1-4]. Spontaneous ideas are the background for conceptual change to be considered in planning teaching strategies in different fields like biology, chemistry and physics [5-11].

Research in science education claims [1,12-14] that descriptive studies are insufficient to understand learning and construction of intuitive ideas. Therefore it's important to identify how these ideas are constructed [15] and their role in the learning process [7, 16]. So we have to study the schemes of representations of reality and to interpret reasoning sequences during learning [17-18].

Pupils relate "gravity" to free-fall on the Earth, or to "Earth attractive force", and sometimes they linked it inextricably to the presence of air or to magnetism [6, 19, 20]. Nussbaum, Novak ([21]) and Arnold [22, 23] have investigated elementary school children's ideas about the Earth's shape and its relationship with the gravitational field; Galili end Bar [23] studied the connection between gravity and weight, and between gravity and the dimension of an object; Osborne 1981, Smith 1992, Berg end Browner [24] the one between gravity and motion. Finally, recent studies [25] have the purpose to identify students' alternative conceptions and scientifically acceptable conceptions about gravity.

The explanation of gravitational attraction has always been problematic, either historically or in teaching research, where it is difficult to define and relate different concepts like "action at a distance", "force of gravity", "gravity" and "weight" [6, 20, 26, 27]. Our purpose is to explore interpretative reasoning sequences of free-fall and to analyze the role of an analogous *material* model, in order to realize resonance between the observation (of free-fall) and a more general interaction of masses. The goal is to overcome the local point of view that identifies free-fall with an attractive force of the Earth.

Causality (efficient and contingent cause [28-30]) is important to identify significant physical quantities, like force and distance, related to the interpretation.

Features of childrens interpretative predictions, referring to quiet and moving objects behavior in the part of the "gravitational field" represented by the model, are very important to explore how pupils are able to recognize the role of boundary conditions in interacting systems.

2 Method, instruments and procedure

Informal context help to activate spontaneous thinking [31-32], by constructing a connection between common experience and scientific knowledge.
Childrens' (age from 5 to 9) spontaneous ideas have been explored: 12 primary school classes participate in an activity in the informal context of scientific culture dissemination, that includes the interactive exposition GEI ([33-35]), organized every year for schools of the area. The groups of 74 children who participate in this activity were randomly selected between all the participants (258 children). Reflections about free fall and gravitational force are proposed by interviews with small groups of 3-7 children prepared according to the protocol, that consider these key points: the concept of action at a distance, the role of field lines, the trajectory of an object moving in a field and the field concept as a physics entity.
The protocol has been prepared by considering disciplinary, historical and cognitive conceptual knots pointed out in the literature [2,5,6,13,16,17,19-23,25, 26,36]. It's formed by a first part of stimulating questions and of drawings that revealed spontaneous ideas, and a

second part of discussion about the use of the analogical material model.

Three inquiry instruments were used: 1) conversation with stimulating questions about conceptual knots considered and some parts of Rogers dialogues [37-39] in order to explore learning sequences, 2) a written questionaire based on graphs and icons, in order to explore childrens' intuitive ideas about Earth gravitational attraction and gravitational field lines [22], 3) gravitational field model proposed by Eddington [40], composed of a big rectangular box covered with a tight elastic cloth: when a heavy sphere, representing the Earth, is put on the membrane, it deforms creating an hyperbolic curve; resting or moving masses, with different velocities, are put upon that surface .

3 Conclusions.

The term "gravity" both in everyday language and in many text-books is used without specifying the physical quantities, that give it sense; many concepts are then associated to that term: force, field, gravitational acceleration and gravitational potential. This creates confusion to students who see in only one term for physics concepts with different properties.

In the interviews children were asked to explain free fall, but only when they mentioned explicitly "gravity" or "gravitational force", then they were requested to explain. Instead of define or giving a meaning, they preferred one of these solutions: a) explain the situation, describing what happens in presence of "gravity"; b) give to the Earth this particular property (uniqueness of Earth system); c) (not frequent) relate it to interaction between two masses. Mostly they associate "gravity" concept to the force one, and force concept to the "action" one, or in general they associate "gravity" with the effects it produces. Sometimes gravitational force is considered as an animate entity, which is able to attract, or it's considered as an intrinsic property of the objects (" the ball has gravitational force").

Childrens' interpretative vision about free fall has two aspects: causality (contingent rather than efficient) and the representative context (local: the Earth attracts objects, rather than the global one of two masses' interaction).

Free fall on the Earth is motivated by children with the fact that objects are not held by themselves ("we let them / we did not held them") or by the medium ("air doesn't support them") or by "gravity" (reverse gravity concept) [6,19]. The last case can be considered as a request of system equilibrium conditions.

Gravitational force is also imagined like a "big magnet that keeps our feet glued on the Earth" or like a "magnet that attracts everything towards the center to the Earth": it's interesting to observe that children remark analogical phenomenology and connect gravitational and magnetic phenomena before its treatement in school.

It seems that some typical answers, interpreted in the literature respecting disciplinary knots, have different roles in spontaneous learning sequences. Some examples: 1) the use of air as a reference of space; 2) increase of weight with the height above the ground like a primordial concept of potential energy; 3) the relationship between force and weight is not relevant in the questionary as a cause of free fall ("the ball falls because it's heavy") and doesn't emerge weight conception as a pressing force related to feeling of heaviness or to object form [19].

The analogical material model helps interpretative prediction of resting and moving objects behavior in the part of the field represented, and we propose it as a connection between a local vision of Earth gravitational field and the vision related to gravitational properties of every mass interacting with another one. Children's intuitive models are sometimes in conflict with it, but the informal context allows the discussion about the best interpretation of the situations examined, and to recognize that the proposed model give them an interpretative representation, because it explore conditions that allow the prediction.

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Herrera, L, Magli, G & Malafarina, D 2005, 'Non-spherical sources of static gravitational fields: Investigating the boundaries of the no-hair theorem', General Relativity and Gravitation, vol. 37, no. 8, pp. 1371-1383. https://doi.org/10.1007/s10714-005-0120-1. Herrera L, Magli G, Malafarina D. Non-spherical sources of static gravitational fields: Investigating the boundaries of the no-hair theorem. General Relativity and Gravitation.Â The model is used as a toy in investigating various issues related to the directional behavior of naked singularities in static spacetimes and the black hole (Schwarzschild) limit. AB - A new, globally regular model describing a static, non spherical gravitating object in General Relativity is presented. In physics, a gravitational field is a model used to explain the influence that a massive body extends into the space around itself, producing a force on another massive body. Thus, a gravitational field is used to explain gravitational phenomena, and is measured in newtons per kilogram (N/kg). In its original concept, gravity was a force between point masses. Following Isaac Newton, Pierre-Simon Laplace attempted to model gravity as some kind of radiation field or fluid, and since the 19th century