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Social marking and conceptual change: the conception of light for ten-year old children

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Abstract. This research project investigates the role that social mediation plays in the destabilisation of preconceptions of the concept of light among the primary school pupils. The resistance that this system of representations shows in the attempt to destabilise it has been studied with two groups of 10 years old children. One of the groups (the experimental) participated in a teaching process which aimed to lead pupils to cognitive conflict; the second (the control group) followed traditional teaching methods. In all experimental situations that were studied the difference between pre-test and post-test was significant for the subjects of the experimental group both at the level of explanation of the transmission of light, and at the level of the stability of cognitive acquisitions.
Key words*:* didactics of physics, pupils´ representations, geometrical optics.

Introduction: Social marking and conceptual change

The aim of this paper is to present the results of an experimental teaching intervention based on the notions of social marking and socio-cognitive conflict concerning the recognition by children of the entity of light. Children's thinking from the point of view of concept formation and phenomena representations of the physical world has already been extensively studied in the fields of Science Education and Educational Psychology (Driver, Guesne & Tiberghien 1985. Lemeignan & Weil-Barais 1993). Thus, it has been realised that explanations pertaining to pupils' thought about the light is not entirely compatible with scientific theories. This underlines the need for organizing suitable teaching for achieving conceptual change (Di Sessa & Sherlin, 1998. Duschl & Hamilton, 1998).

It is in this perspective that we studied children's representations of light as well as their change after a teaching intervention based on cognitive conflict. The model of Geometrical Optic provides the framework for discussing these representations. According to this model light is an entity in space that is independent from light sources and its respective results.

The second starting point of our study is Piaget and Garcia (1971) assertion that transitive thought (if A→B and B→C, then A→C) even though it is a logico-mathematical in nature it can nevertheless be expanded so as to be applicable to entities like power, heat or light as an indirect natural transition. Indeed for a child at the stage of pre-operational thought, the approach to light as a concept centres on the light sources (LS) and visible lighted areas (VLA) or their combination via a thought of direct transition of the following form: LS→VLA. As a result, children at this stage ignore the space in which light bundles propagate, that is to say, the space of light's propagation (SPL). In contrast, operational thought is characterized by a particular form of mathematical transition: LS→SPL and SPL→VLA ➔LS→VLA.

Therefore, according to Piaget and Garcia (1971) in the case of natural transition, the correlation among the elements of the problem of propagation of light, operates as a general model of representation about light. The representation of light based on transition is important because, as a two-step procedure, it imposes the identification of the presence of light in space. The acceptance of light as an entity that is transmitted independently from the light source and the final receiver, constitutes the necessary convention and beginning of the construction of other associated phenomena of light. For example, without the identification of light as an entity it would be impossible to understand the process of the notion of a straight path of light.

At this point it should be stressed that understanding light as an entity in space has previously been identified in a series of studies from 5 to 16 year old students. Research based on various experimental procedures had excluded the presence of light in space in children's thought. Thus it seems that pupils' thought concentrates more on light's sources or bright bouncing areas (Tiberghien & al., 1980. Stead & Osborne, 1980. Anderson & Kärrqvist, 1983. Guesne, 1985. Osborne & Black, 1993. Langley, Ronen & Eylon, 1997. Kok-Aun & Hong-Kwen, 1999. Ravanis, 1999. Mendoza Pérez & López-Tosado, 2000. Galili & Hazan, 2000).

For Doise and Mugny (1981), social marking characterizes situations in which the subject establishes, on a psychological level, a matching between the principles that derive from knowledge or conceptions connected with social relationships, and principles that derive from the cognitive organisation's level. This kind of matching is important for the subject's conceptual development because it includes a social adjusting factor. This factor imposes solutions to social conflicts and causes new cognitive coordinations. During the past twenty-year period research on the learning process, has observed the significance of social marking in children's cognitive development through socio-cognitive conflicts (De Paolis & Mugny, 1985. Girotto, 1987). The importance of social marking has also been corroborated by other research that does not invoke the mechanism of socio-cognitive conflict for cognitive development, but uses instead interventional operations of the social environment such as the destabilisation of preconceptions (Gilly & Roux, 1988. Gilly, 1990. Ravanis & Bagakis, 1998). According to Gilly (1990), social marking allows the movement of more developed cognitive procedures in comparison to cognitive procedures where social marking is not in operation. Such an attempt has created a base in which educational interaction allows the subject to elaborate a common system of meanings jointly with the researcher. Consequently, we assume that subjects that have participated in experimental procedures of cognitive destabilisation will be able to make estimations more easily than subjects who have not attended the class lesson about the propagation of light into space as an independent entity.

Methodology

Subjects

104 subjects (52 boys and 52 girls) of 9,5 to 10,5 years of age (mean age 9,94) from 11 different classes of the fifth grade of primary school participated in this research. These classes were in the vicinity of some areas of Patras thus they shared similar social features. Children's parents had not had any university education while the total number of the years of their main studies ranged from 12 to 24 years. These subjects were selected after a pre-test on a sample of 132 children. The criterion for the selection of

104 out of 132 subjects was based on their failure to respond to two out of the three tasks that we set on children's representations about the concept of light. The children that indicated pre-operational thought were randomly separated in two equal groups of 52 children each; the experimental group (E.G.) and control group (C.G.) respectively.

Procedure

By means of experimental intervention, we have tried to guide children's ideas about light. More specifically, we have tried to help children to move from pre-operational thought towards operational ones based on the model of Geometrical Optics which conflicts with their own ideas. The destabilization of representation was attempted through socio-cognitive conflicts, view which is based an a theoretical model of cognitive development (Doise & Mugny, 1981. Perret-Clermont, 1986). The socio-cognitive conflict appears when an individual trying to solve a problem is deploying a particular strategy which remains totally opposed to someone else's strategy. In such a situation, new thought patterns could emerge out. "The basic principle of this approach is simple. The child's cognitive development is accomplished when she/he participates in social interactions that lead to an intellectual construction since they cause conflict to the participants' answers" (Carugati & Mugny, 1985, p.61).

This conflict could result in the construction of new conceptions, at an operational thinking level (Stavy & Berkovitz, 1980. Ravanis & Papamichael, 1995). In our research, a socio-cognitive conflict is presented as a socially marked concept: "*the travel of light in space*". The metaphorical concept "travel" is connected with an object's displacement in space. In other words, it connects the beginning and end with their displacement through material means.

In our case, the concept "travel" appears in the interaction as a result of the researcher's intervention during the experimental procedures. From the methodological point of view, we did not organise a classical experiment of socio-cognitive conflict that took into consideration the interventors' age an adult as opposed to being the same age as the subjects. Certainly, it is not a case of guiding the subjects, since the tester does not help with the solution of a problem through the internal feelings implicit in a social relationship. Instead, s/he appeals to an already known social concept. We could probably mention guidance to social marking.

In specific terms our experimental design consisted of three phases: (a) pre-intervention data collection (after pilot exploration); (b) intervention; (c) post-intervention data collection. During both pre and post tests children were asked questions concerning three tasks (which are presented in the next paragraph).

Concerning the first and the third phases (pre-intervention and post-intervention) our data of children's ideas were collected through individual interviews. These interviews lasted roughly 10 minutes and took place in the school laboratory. The analysis of the data was based on the transcribed text of the interviews as well as on the individual protocols of the particular observation. During the interview we asked the subjects to tell us where there is light in the experimental sets and to explain their choice. This was done for all three tasks. The pre-test was held two months before the teaching interventions. The two post-tests were held two and four months later.

Regarding the experimental teaching intervention our aim was to create conditions that could induce the thought of the experimental group to socio-cognitive conflict. Two months after the pre-test, a researcher of our team the intervention was made by. In this groups of 3-5 children were taught in the school laboratory. Its duration was the same as the teaching of "light" in the original classroom settings.

On the basis of the one-step scheme (i.e. source-receiver), we presented to the EG the two-step scheme (i.e. source-area of diffusion and area of diffusion-receiver). Here we tried to shift subject focus from a model concentrated on the light source or the receiver to the other to connect them with light as an autonomous entity. Having this purpose, we asked the E.G. two questions: a) "where does light come from?" and b) "how does light come to us?". In answering these questions, we presented the characteristics of the Geometrical Optics model adding the "travel" of light in space as an element of socio-cognitive conflict. We explained that light comes from light sources, for example, the sun or lamps, and travels in space towards other planets or us. We also analysed the direction of the sunlight to the earth through the space and atmosphere of the clouds using light and its rays as equivalent concepts; we also made a geometrical form of light in space. Next, we presented a picture and a sketch in which bundles of light are visible stressed on a known picture from everyday life of a brightly lit bundle of light in the air. We asked them to explain this picture having in mind the light's absence in space. As a result, children's thought came to a dead-end. Then we repeated "*travel of light*" and thus finished our experimental teaching intervention.

The children of the C.G. attended a teaching procedure where the fifth grade curriculum was accurately presented. This teaching was based on the earth's light as coming from the sun as well as the use of light sources in everyday life. The role of the sun was fully analysed and some details were given about its internal nucleus, the layers and surface. Furthermore, the role of light sources was explained and the difference between self-lit and hetero-lit objects was presented. The whole procedure was based on a rich material of designs and pictures where light's presence in the entire space in the form of light bundles is recorded. In other words, light is being searched by sight in the air. All this material was taken out of the school textbook.

Therefore, the difference between this procedure and the experimental teaching intervention in the E.G. consisted in an absence of reports concerning the meaning of "travel", the unified figure connection of both the points of departure and arrival as well as the travelling distance made by means of matter.

Tasks

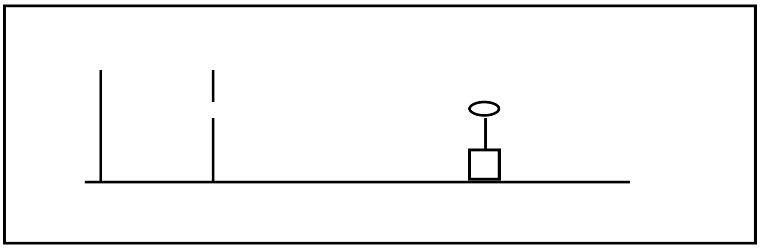
In the three tasks we created situations that permitted concentration on light's sources and lighted surfaces as well as recognition of diffused light in space. In this way, we considered that when children can locate light in space independent of its sources and that results in surpassing their perceptive centrations, they dispose the schemata of transitive thought and thus are able to construct scientific concepts of light.

Task 1: In a directly sunlit room, we switched on a table lamp. We asked the children to show us, at least, three points in space having light. Afterwards, we asked the children to give as many answers as possible. In this way, we would be able to safely confirm, whether they recognised the existence of light in the space or not.

Task 2: We directed a straight beam of light from an electric torch by an electrical torch (3V, 1,5W) towards a vertical surface at a 3 m distance in order to form, a visible light spot on the surface. While the torch was on, we asked the children: "where is there light coming from the torch?". In the case that the subject only answered the torch's lamp and the lit spot, we once more indicated the space in-between the torch and wall which is a non-visible during the day light. We then asked: "In the air, between the torch and wall, is there any light?". At this point, the children were presented with an experimental situation that was more than familiar to them from their everyday life, the light bundle is visible when the light diffused in the same space is of low intensity. However, at the time of the interview, the light was not visible in space. If that had been the case, a searching through vision would have been enough to lead to an answer resulting from the simple concentration on the light beam and not from a transitive thought. From a methodological point of view, such a choice would be unacceptable because that question of our measurement tool would bias our methodology.

We also considered that by purposefully indicating the space in-between the torch and wall exposed us to methodological risks. It is possible for the subject to recall an everyday incident through the intervention of the experimenter. However, this too could destabilize the children’s preconception and could lead to a cognitive problem. But, if a possible positive answer to the question addressed to children provokes the above problem, responses a negative one indicates a kind of a naive thought which points to perceptive stimuli related to a certain situation, a characteristic of pre-operational thought.

Task 3: We set two vertical carton cards (measuring 17cmx25cm) on a stable horizontal base at a distance of 12cm from each other. On one carton, a circular hole of 0.5cm diameter was cut out at a height of 17cm from the base. At the same height as the hole, a portable lamp was placed (4.8V, 2.4W) at a 10cm distance from the hole.



Figure

When the set is presented to the students, we turn on the light and ask: "Is there any light from the lamp between the two carton pieces?" If the answer is positive, we ask for explanations. In case it is negative or the explanations are not satisfying, we ask and show simultaneously: "Here, in the air, is there any light from the lamp?".

For task three, we chose this experimental set because, in contrast with the two other tasks, it is not from an everyday life situation. The beam of light was not visible due to the plenty of light emanating from the surrounding space.

Scheme of evaluation

The scale that we used for checking the changes that appeared between the answers of the two groups' in the pre-test and post-test includes three levels: progress, immobility and retrogression. We consider progress as the transition from pre-operational explanations to operational level's explanations. Therefore, this is a transition from answers of conceptual concentration to explanations based on the recognition of light as an independent entity in space. We consider immobility as being the insistence on the same answers in both the pre-test and post-tests, and retrogression as the change of an answer initially compatible with the model of Geometrical Optics to an answer of the pre-operational level.

Results and Discussion

The Mann-Whitney test was applied in order to establish whether the differences between two independent samples coming from the same population were statistically significant or not. We consider the differences between the two groups statistically important at an 0.05 level of significance.

In all three tasks the answers given are based on the same representation models and are classified in the same two categories, in both the pre-test and post-tests (table 1).

Table 1. Frequencies of answers of subjects of experimental and control group on three tasks

		PRE-TEST		A POST-TEST		B POST-TEST	
		E. G.	C. G.	E. G.	C. G.	E. G.	C. G
Task 1	Cat. A	6	8	28	7	34	8
	Cat. B	46	44	24	45	18	43
Task 2	Cat. A	23	18	44	28	5	20
	Cat. B	29	34	8	24	47	32
Task 3	Cat. A	11	9	41	25	43	27
	Cat. B	41	43	11	27	9	25

The analysis indicated the following:

a) The existence of light in space or in the air, which means in areas where light is visible, is recognised in answers of operational thinking. For example, "here where we are sitting...almost in the whole room....in that room...(task 1). "Just opposite the wall and between the light's course..." (task 2). "On the wall, it passes from here and there is light there...but we cannot see it" (task 2). "There is...a little...from here (she shows the direction of light) to the air...it enlightens the air" (task 3).

In the first task, the answers of this category are the following: the pre-test was 6 for the subjects of the E.G., while the C.G. was 8. In the second task, the answers in the pre-test were 23 and 18 respectively. In the third task, the pre-test was 11 and 9 correspondingly.

b) The light's existence in the light sources or in areas where there are visible spots lit by light bundles is recognised by the answers of pre-operational thought. "There is light where light shines" (task 1)."On the wall...there is light in the torch, in the lamp"(task 2). "No...because the light goes here (to the hole) and straight here (to the card-board)...it does not go there (to the space) (task 3). During the pre-test the E.G. answers for this category were 46 for the first task, 29 for the second and 41 for the third task. The answers of the C.G. were 44, 34 and 43 respectively.

In the following table 2, we present changes that have been observed from the pre-test to post-test in the answers of both E.G and C.G. subjects. Some children either give implicit answers during the pre-test and post-test, or they fail to respond. Thus, we cannot reach any conclusion about the existence of a change in their evaluation and, since they are not included in the statistical elaboration, the frequency sums are not always the same.

The changes in the subjects' evaluations seem to verify our hypothesis. In the first task for both the first and second post-test, the E.G. subjects showed more progress than those of the C.G. The differences between them are important (task 1, 1st post-test: $U=787{,}5$ $p<0{,}01$, 2nd post-test: $U=654$, $p<0{,}01$). In the second task, the difference is statistically significant ($U=1061$, $p<0{,}02$) for the first post-test but not for the second [although the tendency was obviously towards the E.G. ($U=1109$, $p<0.07$)]. In the third task, the changes in the answers between the post-test and pre-test confirm our hypothesis (task 3, 1st post-test: $U=1010$, $p<0.02$, 2nd post-test: $U=1004$, $p<0.01$).

Table 2. Data of responses by children showing changes between pre- and post-test

		PRE-TEST / A POST-TEST		PRE-TEST / B POST-TEST	
		E.G.	C.G.	E.G.	C.G.
Task 1	Progress	23	2	31	3
	Immobility	28	47	18	45
	Retrogression	1	3	3	3
Task 2	Progress	22	10	25	16
	Immobility	29	42	26	34
	Retrogression	1		1	2
Task 3	Progress	31	18	32	19
	Immobility	20	32	20	32
	Retrogression	1	2		1

From the above results, we can conclude that the subjects of the experimental group are able to recognise light as an autonomous entity in space more than that of the control group.

Therefore, concerning the first task, we observed an important improvement in the answers of the experimental group as far as the recognition of light in everyday context is concerned. Both in the first and second post-tests, it seems that the concentration on both light sources and strongly lit areas declines. Two and four months after attending the experimental teaching intervention several subjects of the E.G., were easily able to show light in some spots of space.

In the second task, our hypothesis is confirmed only in the first post-test but not for the second. In a procedure, which is common in our daily life, that is, the visual verification of light's presence along a torch bundle, the E.G. subjects show stable progress. However, it seems that the C.G. subjects who had attended a non-social marking teaching procedure gradually realised the idea of light's presence in space. This may attribute to the nature of the task that leads to a situation where subjects have already formed representations of static character. However, in each case, the progress of the E.G. was greater.

The confirmation of our hypothesis in both the post-tests of the third task is of great interest. Here we presented an unusual situation for child experience. The E.G. subjects steadily succeeded in recognising light in-between the two pieces of cardboard. This observation needs reasoning based on a mental model completely deconcentrated from the visible characteristics of the experimental situation.

From the above results, we can conclude that the subjects of the experimental group are able to recognise light as an autonomous entity in space more than that of the control group.

From our research, there is evidence that indicates the important role of social marking in the destabilisation of spontaneous mental representations and the structuring of other (compatible with the scientific) models for the concept of light. Indeed, it seems possible with this procedure (as a mechanism of social interaction) to drive psychological prerequisites of the cognitive knowledge to a higher level. This change is probably due to both the evocation of imbalance and destabilisation in the representative models of pre-operational level, and the agitation of assimilative and adaptive operations leading to cognitive re-organisation and equilibration at the level of operational thinking. From the educational point of view, the use of social marking in our research did not aim to create general progress that can lead to intellectual preparation of the subject, so it can absorb the natural ideas. In our scientific field, the Science Education, is not only oriented to the cognitive operation of the subject, but also to the analysis of educational interaction and socially marked experimental situations. Therefore, since our basic purpose is the transition from a descriptive to an explanatory teaching of physical concepts, under the psychological and epistemological perspective of the term, we considered it necessary to study the effectiveness of alternative didactics. This view on teaching and learning is not based on empirical evaluation of education, but on a plan grounded in intellectual representations of the subjects and their transformation. Finally, taking into consideration that the experimental didactical procedure took place in vitro conditions with small groups of subjects, it would be very interesting to transfer this procedure to in vivo conditions (in a school class) and check its width at the level of everyday didactics. However, this is another area of great importance for future research.

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