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ASPECTS OF CONSTRUCTIVISM

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Abstract. An experimental setting was used in a class of 23 sixth-grade students to prompt discussions about shadows. A rectangular wooden block with an incandescent electric lamp, mounted in the middle of each side, consisted the experimental setting. Additionally, there was a fifth lamp that was positioned exactly above the house and could be removed at any time. Each lamp could be replaced by other lamps of different colours and could be turned on and off independently. A two-dimensional model of a house, made of opaque cardboard, was also mounted upright at the center of the wooden block. The model showed a house with an inclined roof, a chimney, and one door and two windows that were represented using three movable pieces of cardboard. Students were asked to predict the position and other characteristics of the shadow when (a) each one of the five lamps was turned on individually, and (b) two lamps mounted on opposing sides of the wooden block were turned on simultaneously. Discussions were facilitated in order to create cognitive dissonance in students' thinking and support the consequent psychological process of equilibration through a collaborative negotiation of students' diverse understandings. The transcribed discussions were analyzed in an attempt to exemplify the importance of the social interaction between students' knowledge schemes and their experience with the environment (physical and human), as well as aspects of the scientific epistemology and their relevance to conceptual change.
Key words: *science education, constructivism, alternative conceptions, conceptual change*

Introduction

Research on student cognition has clearly demonstrated that students' prior conceptions create a framework for understanding and interpreting information gathered through experiences (Brickhouse, 1994; Feher &Rice, 1986, 1987a, 1987b; Guesne, 1985). Learning results from the interaction occurring between an individual's experiences and his or her current conceptions and ideas. The process of learning depends on the extent to which the individual's conceptions integrate with new information. This integration is characterized as assimilation or accommodation and is guided by the principle of equilibration whereby individuals seek a stable homeostasis between internal conceptions and information from the environment. The process of accommodation is, however, much more critical for the continuing conceptual development of the learners, because it requires a transformation of individual conceptions rather than integration of new information into the individual's existing frameworks.

The existence and persistence of students' (mis) conceptions in science gave rise to different research efforts to identify conditions that encourage or drive accommodation (e.g., Posner et al., 1982). Dissatisfaction with current conceptions acts as a catalyst for accommodation to occur provided that the new conception is intelligible, plausible, and fruitful. Thus, each time students encounter a discrepant event they search for new intelligible, plausible, and fruitful constructs in an attempt to balance the existing cognitive disequilibrium. Personal construction of knowledge occurs through the interaction between the individual's knowledge schemes and his or her experiences with the environment. The primary mechanism for cognitive growth is the learner's interactions with the physical environment, while the social interactions and language do not receive primary attention. Social interactions and talk with other people are, however, seen as aiding the process of accommodation by creating cognitive dissonance. This description focuses on the psychological process of equilibration and reflects the Piagetian perspective or the cognitive perspective in general.

Conversely, the Vygotskian perspective, or the socio-cultural perspective in general, considers the construction of knowledge as a social process where social transactions and discourse are considered to be the basis for any subsequent learning. Representations of knowledge are viewed as patterned by social and cultural circumstances. This view "accentuates the social and cultural genesis and appropriation of knowledge" (Billett 1996, p. 264). Learning is viewed as the appropriation of socially derived forms of knowledge. Appropriation is not restricted to the internalization of externally derived stimuli. It consists of a transformational and reciprocal constructive process (Rogoff 1995) and results to a co-construction process of cognitive structures (Valsiner, 1994).

The cognitive and socio-cultural constructivism seems disparate, but they offer some basis for considering "the mutuality between persons acting and the social and cultural circumstance in which they act" (Billett 1996, p. 265), and for building bridges between them. Even though both perspectives deal with the construction of knowledge, the cognitive constructivist perspective emphasizes the internal processes of knowledge construction, whereas the socio-cultural perspective focuses on children's cognitive development as it occurs through social interaction, and details the negotiated nature of the reciprocal transformation with social partners. Thus, language, in the socio-cultural perspective is considered essential in socially negotiating and constructing meaning. The widening interest in "situated learning" (Elbers, 1996; Richmond &Striley. 1996, Solomon, 1993) resides in the belief that learning is more closely linked to the circumstances of its acquisition, and that these circumstances influence the transfer of knowledge to other situations. This belief calls for a closer consideration of the contributions of socio-cultural constructivism in understanding the role of social transactions in shaping cognition and the complexities of the situated knowledge of the classroom.

Although the relationship between social circumstances and cognition remains opaque, this paper accepts the potential contribution of both perspectives to the construction of knowledge, and attempts to investigate how carefully designed classroom-based discourse supports students' conceptual growth. The attempt aims at providing students with the opportunity to be involved in discussions and experimentation for the purpose of examining how the knowledge construction process is shaped and validated by students' interactions amongst them, the teacher, and the physical environment. The present study involves an analysis of classroom discourse in an intact class of 23 sixth-grade students during an 80-minute science session. An inventive experimental setting was used in the session to prompt dialogue and exchange of points of view. Discussions were used to create cognitive dissonance, and carefully designed experiments were used for exemplifying aspects of the scientific way of thinking and problem solving. The analysis of the discourse reflected students' conceptions about shadows, the patterns of social interactions and negotiations as these were shaped by the roles students assumed in the classroom, as well as their expectations, and how they progressed toward conceptual growth.

Methodology

Research Procedures

23 sixth-grade students were presented with an experimental setting, which consisted of a rectangular wooden block having in the middle of each side an incandescent electric lamp mounted on it. The four lamps were identical and could be turned on and off independently. A two-dimensional model of a house, made of opaque cardboard, was also mounted upright at the center of the wooden block. The model showed a house having an inclined roof with a projection imitating a chimney. Three movable pieces of cardboard on the model represented two windows and a door that could remain shut or open. Students were asked to predict the position, shape, and color of the shadow when each lamp in turn was assumed to be turned on.

Moreover, students were asked to predict the position and the characteristics of the shadow(s) when the lamps on two opposing sides of the wooden block were assumed to be turned on simultaneously.

The teacher guided the discussion and helped the students realize that there were various predictions and explanations concerning the formation and properties of shadows. Students were then guided to design and conduct experiments in order to verify or revise their conceptions. The experiments to be performed as well as teachers' questions or comments were deliberately selected and sequenced in order to present challenges to ideas expressed during the discussions and examine their effect on the consequent psychological process of equilibration through a collaborative negotiation of students' understandings. The primary intent was to examine the process of conceptual change and how discussions and investigations supported it. The class sessions were audio- and video-taped. The discussions were then transcribed and analyzed.

Analysis of classroom discourse

An in-depth analysis of the ways students negotiated their ideas during the discussions was carried out in an attempt to identify different patterns of interaction depending on students' status in the classroom, their expectations, and the effects of classroom discourse on students' conceptions, motivation, their meta-cognitive awareness, and conceptual understanding of shadow phenomena. Initially, students were involved in discussions related to when and where shadows exist or are formed. This discussion was informal and was carried out in small groups without teacher involvement in an attempt to establish a relaxed classroom environment and encourage student participation. All students agreed that shadows were very familiar to them and that they could identify different shadows in their classroom. The teacher then explained that they would be discussing about shadows during the session and asked the students to sit in a semi-circle having in the center a big table with the wooden block on it. When students were experimenting with the apparatus, the lighting of the classroom was dimmed to allow for the experiments to be carried out. The experimental setting was diagrammatically represented on sheets of paper and it was distributed to the students to draw the shadow or indicate its position. Figure 1 below shows the diagram of the experimental setting and a note explaining the notations that were used.

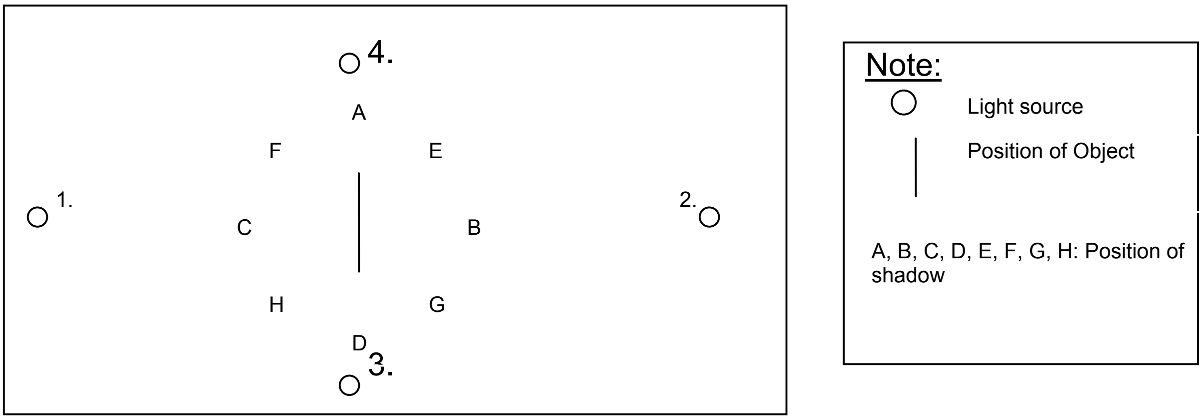

Figure 1: Diagram of the experimental setting

Initial predictions about the size, position, and shape of shadows

The teacher initiated the discussion by asking the students to assume that lamp 1 was turned on and to predict what would happen. All students agreed that the shadow of the object (i.e., the two-dimensional model of the house) would appear, and that it would have the shape of the object. However, when the teacher asked them to draw the shadow using a diagram, students' individual drawings exhibited different understandings. For example, some students selected the correct position, whereas some others insisted that the shadow would appear in front of the house toward the light source. Moreover, it was observed that some students, who were considered the best students in the classroom, were continuously trying to persuade their classmates to accept their ideas, whereas some others seemed reluctant to disagree. Interestingly, almost all students resisted changing their initial conception. The teacher acknowledged the existing disagreement, and continued the lesson by asking the students to draw the shadow for the hypothetical cases of having each one of the remaining lamps turned on individually.

The new drawings revealed further disagreements, which were related to the position, the shape, and the size of the shadow. Specifically, the analysis showed the following: (a) in general, students predicted that the shape of the shadow was identical or similar to the shape of the house irrespective of the position of the house; and (b) when lamp 3 or lamp 4 was assumed to be turned on, students drew shadows that resembled the shape of the house, but of smaller size than the size of the shadows that students drew when lamp 1 or lamp 2 was assumed to be turned on. Interestingly enough, the drawings of the shadows did not show only the "border" of the house but all the details, which appeared on the model including the door, the windows, and the dividing line between the roof and the rest of the house.

Additionally, some distorted shapes of the shadow of the house also appeared when the teacher asked the students to predict and draw the shadow of the house for the cases when each lamp was in turn turned on and the door and the windows were kept open. For some students, keeping the door or the windows open or closed did not make any difference and therefore their diagrams didn't differ in comparison with the ones they drew before. In some other cases, the drawings projected the idea of a three-dimensional drawing and by looking at the shadow you could even locate the exact position of the movable cardboard pieces representing the door and the windows.

After these initial predictions, the students asked their teacher to provide them with the correct solutions and explanations. The teacher responded that "doing science" means that students have to find a way to work out the correct answers. Interestingly, none of them proposed to experiment with the available setting that was in the classroom. But, they insisted that the teacher should provide them with books and guides to help them find the correct answers. The teacher instead raised questions related to the nature of shadows. The following excerpt is indicative of the discussions that followed and students' conceptions of shadows.

Teacher (T): You drew the shadow here (in front of the house towards the light source). Why? What is the shadow for you?

Student (S_1): The shadow is the self of the .. thing.. of the object .. of the house. It is that thing which goes always with them (the things or objects). It never happens to be away from them.

…

T: You told me that shadows are "the selves of the things". How do "the selves of the things" behave? What about our shadows? Do they walk? Do they speak?

All of the students are laughing and the student hesitates to reply, while a student sitting next to her intervenes.

Student (S_2): Our shadows do not walk or speak, but we always carry them with us. Wherever we go, our shadows are always there.

T: Do we carry them or do they follow us?

This question triggered opposing points of view in the classroom. Specifically, there were students who favored the idea of the shadow "accompanying" the objects, as well as students who supported the view that shadows are "carried by" the objects. Furthermore, as indicated by the following statement, there were also students who strongly supported the view that shadows do not exist independently of the existence of light.

Student (S_3): (Without waiting to be called on). I think that this is not true (referring to the "accompanying" or the "carried by" shadow). In such a case, where is the shadow if we do not have a light source? Can you see the shadow?

Again. this question split the class into two groups quarrelling whether shadows exist independently of the existence of light and thus light only makes them visible, or whether shadows are "caused" or "formed" when light is present.

The verification or refutation of initial predictions

At this point, the teacher felt that it was the proper time to use the experimental setting. Students listed points of disagreement and with the help of the teacher agreed upon which experiments to perform in order to investigate the different points of view and resolve their disagreements. The previous discussions aroused students' interest and motivation to propose and perform purposeful investigations, and get involved in the accompanying discussions. Progressively, these discussions helped the class reach consensus about the position and the shape of shadows. The idea that the shadow belongs to the respective object was, however, so strong that students resisted to change it. Therefore, when they were confronted with a shadow having a different shape than the object (i.e., when lamp 3 was turned on), they insisted on providing different pseudo-explanations, and repeated the respective experiment a number of times as if there was something peculiar about it. They progressively concluded that both the direction and the shape of a shadow are related to the position of the light source, but they did not grasp yet the meaning of a shadow as the absence of light, when blocked by an opaque object. The teacher wrapped up what they had been doing so far, and the students unanimously concluded that they had been involved in quite interesting activities and that they developed new insights about shadows.

Subsequently, the teacher initiated new discussions by asking the students to predict whether a letter written on the surface of the experimental setting could be seen when the shadow appeared toward the letter's position, or draw the shadows when a colored light bulb (i.e., green, red, or yellow) was used. These questions prompted new "turmoil" in the classroom. Progressively, students became less reluctant to voice their opinions or to disagree with their classmates' opinions. More students were also complaining that they were not given enough opportunities to participate in the on-going classroom discourse. The teacher, in an attempt to alleviate students' complaints, adopted a voting strategy after the discussion was progressing towards saturation (i.e., there were no longer any new ideas). Specifically, the teacher noted on the blackboard all different perspectives, and students were asked to vote for one of them. Students were also given the opportunity to provide additional comments, when they felt the need to do so.

Concerning the visibility of a letter when the shadow of the house pointed toward the letter's direction, some students thought that the letter would be invisible, because "it would be covered by the shadow". Another group of students thought that the letter would be visible, less visible, or invisible depending on the "thickness" of the shadow, but they were unable to explain adequately what factors affect the thickness of the shadow. The prevailing idea was that the thickness of the shadow depended on the dimensions (the thickness) of the object. Suddenly, a student who was reflecting on her real life experiences voiced her objection:

(S_3): No .. No, I think that the letter will always be visible. The thickness of the shadow does not affect whether we can see the letter.
(S_4): I do not agree. Think about a … very thick shadow. How can you see something in the shadow?
(S_3): Yes ….you can.... Think about being in a forest … under the shadows of dense planted and …bushy trees. You play games there, you do other things. How can you play or do things if you cannot see?
(S_5): Yes, ... but in such a case you are stepping on the shadow.
(S_3): No ... yes ... but the shadow does not cover the ... the stones ... other things or ... the ground.

These comments prompted new discussions and students started changing their opinions. During the voting process, none of them supported the invisibility of the letter, and most of them voted that "it depends" without being able to provide adequate explanations. When they were asked why they changed their views although they strongly supported them in the preceding discussions, they responded that they were not sure whether the letter would be visible, but that it was safer to vote for the alternative "it depends" because of their uncertainty. Some of the students were more susceptible to adopting their classmates' points of view, and they usually suppressed their own opinions, and voted according to the opinions of either their friends or the best students in the classroom. This classroom strategy prevented them from being cognitively engaged in the on-going activities.

During the discussions about the color of shadows, when colored light sources were to be used, students expressed ideas, which indicated that they considered shadows to represent the presence of something belonging to the respective object and having material characteristics rather than the absence of light. They supported that the shadow of an object would be red, green, or yellow depending on the color of the light source, and, in some cases, that the shadow would have a color different from the color of the light source, even though they were unable to logically reason about their arguments. Some students raised, however, objections insisting that they had never seen colored shadows. The former group responded that this was true, because in everyday circumstances the light sources are usually colorless. There were, however, indications that the diversity of views concerning the same phenomena induced students to start re-considering and even changing their initial conceptions in the light of the different perspectives, which were manifested during the discussions. Thus, during the voting process, the majority of the students responded that they were not sure whether the shadows would have the same color as the light source or whether shadows would be dark.

Students continued to struggle for greater participation in the discussions and were complaining because some of them dominated the speaking floor. Students also exhibited more positive attitudes towards experimentation and, early in the discussion, they proposed to resort to the experimental setting to resolve the opposing views manifested during the discussions. They started to respect the different views about the same phenomenon, and they considered the different points of views as an opportunity for experimentation and fruitful interaction with their classmates and the teacher. The experimentation and the accompanying discussions helped them to both consolidate their revised conceptions about the shape and the position of the shadow and to establish consensus regarding the visibility of a letter covered by a shadow and the color of a shadow "caused" or "formed" by a colored light source. Experimentation and discussions induced students to think and reconsider their initial conceptions about colored shadows. Hence, they started wondering why the shadows did not have the color of the light and whether shadows are nothing more than absence of light.

Conclusions and implications for science teaching

Classrooms are supposed to be learning communities where "the teacher is charged with the responsibility of establishing shared understandings" (Scott 1996, p.325) of portions of the publicly available knowledge. Thus, teachers, and science teachers in particular, feel obliged to organize learning activities, which will facilitate the learning process and ensure that their students acquire knowledge that is socially acceptable.

This culturally perceived obligation often translates into a disseminationist approach of teaching where teachers assume the responsibility to transfer knowledge to the heads of their students. They usually assume an authoritarian role in the classroom, and control every instructional activity. In response, students behave and act according to what they perceive to be their teachers' expectations. Teachers heavily dominate classroom discourse, and without any doubt a teacher-centered approach discourages students' collaborative construction of meaning.

A constructivist view of learning asserts, however, that learners are builders of knowledge structures and not passive recorders of information. The conditions of an individual's process of knowledge construction can be traced in structures developed earlier and in the specific opportunities to act that are provided by the learning environment. Ideas, which refer to the influence of the social conditions in which learning occurs, appear in both the cognitive and socio-cultural constructivism. Even though these two perspectives view the construction of meaning differently, taken together they seem to have the capacity to enrich our understanding of the knowledge construction process and transform our views about teaching and learning.

In the present study, the teacher attempted to engage sixth-grade children in discussions and investigations in order to construct theories and explanations about shadow phenomena that are consistent with canonical science. Discussions and investigations were carefully orchestrated to (a) improve the likelihood that children would recognize the diversity of predictions and explanations about different shadow phenomena adopted by them, and (b) establish consensus about the explanations the teacher wanted them to accept. Particular attention was given to instances in which the children were largely in disagreement during the meaning-making process.

The findings of the study illustrate that students made strong progress toward achieving correct understanding of shadow phenomena. They became also highly motivated to be involved in learning activities. Their engagement was substantial as reflected by the length of the discussions and the number of individual students who participated in the discussions. Levels of students' engagement progressively rose and their arguments became more sophisticated. They also became more tolerant and less critical of their classmates' conceptions and were willing to suspend final judgment waiting for evidence to be collected through purposeful experimentation. Consequently, they exhibited more positive attitudes toward experimental work and their motivation for learning as well as their awareness about learning processes seemed to be highly enhanced.

The patterns of achievement, engagement, and motivation were not, however, universal and depended largely on the dynamics of the classroom and students' expectations. The dialogue among students often indicated authoritarian interaction, because of the students' different status in the classroom or their different conceptions and motivation. Discourse in the classroom revealed, furthermore, that students' conceptions were less or more resistant to change through social interaction among the students and the teacher and the accompanying experimentation, and elicited rich and useful information about the knowledge construction processes. Conceptual change does not seem to be an all-or-none phenomenon but a gradual process that depends not only on the learners' past experiences but also on contextual constraints.

It becomes important to intensify research about how specific situations and social dynamics influence the construction of knowledge. "Work on cognitive development has recently entered a phase in which theorists are beginning to stress a complex link between contextual constraints and the acquisition of knowledge" (Jarvella, 1966, p.350) and accept the complementary role of the cognitive and sociocultural constructivism. Contributions from both perspectives collectively seem to offer the potential for a better understanding about the situated knowledge of the classroom, its internal processes and the conditions that shape its construction.

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Резюме

АСПЕКТЫ КОНСТРУКТИВИЗМА

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Экспериментальная установка использовалось в шестом классе (23 ученика), чтобы побудить обсуждения о тенях. Экспериментальная установка: прямоугольный деревянный блок со сверкающей электрической лампой, установленной в середине каждой стороны. Дополнительно, была пятая лампа, которая была помещена точно выше дома и могла быть удалена в любое время. Каждая лампа могла быть заменена другими лампами различных цветов и могла быть включена/выключена независимо. Двух-мерная модель дома, сделанного из непрозрачного картона, была также установлена вертикально в центре деревянного блока. Модель показывала дом с наклонной крышей, дымоходом, одной дверью и двумя окнами, которые были представлены, используя три подвижные части картона. Учеников спрашивали предсказать положение (позицию) и другие характеристики тени, когда (a), каждая из этих пяти ламп была включена индивидуально, и (b) две лампы, установленные на противостоящих сторонах деревянного блока, включенных одновременно. Обсуждения были облегчены, чтобы создавать познавательное разногласие в размышлении учеников. Обсуждения были проанализированы в попытке иллюстрировать важность социального взаимодействия между схемами знания учеников и их опытом с окружающей средой (физической и человеческой), также как аспектами научной эпистемологии и их уместности к концептуальному изменению (замене).

Ключевые слова: естественнонаучное образование, конструктивизм, альтернативные концепции, концептуальное изменение.

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