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RESEARCH REPORT

What is the relationship between social constructivism and Piagetian constructivism? An analysis of the characteristics of the ideas within both theories

N. Marín, Dpto. de Didáctica de la Matematica y de las Ciencias Experimentales, Facultad de Ciencias de la Educación, Universidad de Almería, Spain
A. Benarroch, Dpto. de Didáctica de las Ciencias Experimentales, Escuela de Magisterio de Melilla, Universidad de Granada, Spain
E. Jiménez Gómez, Dpto. de Didáctica de las Ciencias Experimentales, Facultad de Educación, Universidad de Murcia, Spain

For twenty years, social constructivism has been a paradigm in science teaching and not an easy bedfellow for piagetian constructivism, even though both have had the same thing in mind . . . a study of the learner. For this reason we attempt to find connections and bridges between them so that both may be enriched, to the benefit of science teaching.

Introduction

At the end of the seventies there was a move in science teaching away from an interest in general aspects linked with pupils' cognitive level towards specific aspects of their knowledge related to the content to be taught. At the same time, divisions were opening up which would lead to the different constructivist currents which we know today (Good 1993, Matthews 1994, Geelan 1997).

Piagetian experiments with children had a great effect on science teaching in the 1960s and 70s (Bliss 1995). Later, a new language was adopted by educators and researchers to describe science teaching problems, giving rise to a new 'theory', in a postmodernist sense (Solomon 1994), which came to be known as the 'alternative conceptions movement' (Gilbert and Swift 1985) and later 'social constructivism' (Gilbert 1995). One characteristic of social constructivism (SC) was the constant criticism and, indeed, rejection of Piagetian constructivism (PC) (see Posner *et al*. 1982, Novak 1982, Gilbert and Swift 1985; Giordan and De Vecchi 1987, Millar 1989, Séré 1990, among others), which seemed to suggest that the two points of view were irreconcilable. The critics of Piaget's theory thought it was outdated, a view which seems unfair since it did not take into account the post-mortem continuation of his work (see Vuyk 1985, Aliberas *et al*. 1989, López

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Rupérez 1990, Monk 1990, Perales 1992, Pozo *et al*. 1992, Shayer 1993, Lawson 1993, Niaz 1994, among others).

Even if we accept as valid some of the criticism directed at Piaget's theory, especially that referring to intra and interstage development 'décalage', (Vuyk 1985), we suggest that since the children and adolescents described by PC and SC interact with a similar natural and social environment, the results concerning cognitive characteristics should converge or, at least, not be far apart. The question we pose is the following: is there some point in common between student's cognitive characterization using the theoretical framework and research methodology of PC and that reached by SC? In this contribution, we attempt to answer this question since if bridges can be made between SC and PC we can begin to reconcile both camps open up paths to advance and improve both the teaching and learning of science.

Preliminary remarks

We must first establish the meaning which we shall assign to the terms *conception* and *schema*, both of which will be used frequently in this work. In this way we hope to avoid confusion and, at the same time, define our position. Although the paper is firmly set in the field of science education, there will be occasional sorties into the domain of cognitive psychology. This interdisciplinary nature means that we must be extremely careful since a person from one discipline might misinterpret certain affirmations made about the other.

It is clear that individual knowledge is the subject of psychology and science education, to such an extent that it has become the most productive research line and, in the process, given rise to problems of terminology.

In the field of Science Education, the terms conception and schema are most commonly used to refer to the students' knowledge of the academic content of what is to be taught (Jiménez Gómez *et al*. 1994), although many other terms are also used, such as *children's misconceptions* (Terry *et al*. 1985), *conceptual misunderstanding* (Galili and Bar 1992), *spontaneous ideas* (Viennot 1979), intuitive 'law' or *spontaneous reasoning* (Viennot 1979), views (Boeha 1990), *conceptual framework*, *students' beliefs* or *students' conceptual categories* (Finegold and Gorsky 1991), *rules* (Maloney 1984), *spontaneous models* (Villani and Pacca 1990), *implicit theories* (Montanero and Pérez 1995) etc.

The term schema is used to represent a group of common and coherent concepts (Viennot 1979), students' ideas which are coherent with their experiences (Watts and Zylbersztajn 1981, Watts 1983, Terry *et al*. 1985), perspective from which the students' answers to different questions can be predicted (Finegold and Gorsky 1991), a group of ideas which shows a certain consistency towards the same concept presented in different problem areas and contexts (Kuiper and Mondlane 1994), a network of relationships which constitutes the knowledge of facts and phenomena used by a child (Ruggiero *et al*. 1985) etc.

The term conception is associated with categories of replies (Noce *et al*. 1988), meanings constructed by an individual to make sense of the world (Thijs 1992), students' ideas extracted from erroneous responses to a physical situation (Galili and Bar 1992), students' conceptualizations as deduced by the investigator from their descriptions and explanations (Twigger *et al*. 1994), students' explanations of a given physical fact (Montanero and Pérez 1995), etc.

It seems that different terms are frequently used to refer to one meaning, suggesting that the issue of one term does not necessarily imply a definite meaning.

Cognitive psychology frequently uses the term schema to explain learning, the understanding of texts, the representation of facts, the recognition of visual patterns, etc. although the 'qualities' given to the schemas in information processing theories differ from those given in a Piagetian context (Pozo 1989).

In Piagetian theory it is usual to give meaning to the term schema by genetic or functional references. For example, preoperational schemas arise from interiorized sensomotor schemas of action; when these are reversible they become operational schemas (Piaget 1977b), they provide meaning, have a transformational capacity and above all, are the support which give rise to assimilation and accommodation processes (Piaget 1977a). According to Pascual-Leone (1979), schemas are constructs which enable 'rational reconstructions' to be made about the subject's psychological activity; they have a chain of interrelated properties which are activated by given external factors and a component which executes both internal and external actions.

Although not exhaustive, this outline of how the term schema is used in both disciplines is sufficient to identify two clear tendencies in its use:

- A characteristic which alludes to some type of regularity in the students' responses. This is the meaning given in most science education studies.
- A theoretical construct which makes it possible to understand or explain the subject's non-visible psychological activity, a meaning alluded to in most of the cognitive psychology studies consulted.

One weakness in this division is the fact that the schema as construct is only a rational reconstruction made from the regularities found in the subject's response to a task. How then can we distinguish between both meanings? The bibliography consulted in the field of psychology leaves no room for doubt: the schema as construct forms part of the theoretical psychological network used to categorize, group and interpret the subject's response, which is not the same thing as considering the schema as the regularity (Marín 1998). Described thus, the schema can be related to other constructs of knowledge theory such as short-term memory, operational level, cognitive strategies, cognitive style etc. which would be impossible in the absence of a theoretical framework which contained these constructs. This would be the case when the students' responses are evaluated according to their distance from the expert's response; in this case the search for regularities is eminently inductive since there is no theoretical cognitive network to guide these methodological procedures (Jiménez Gómez *et al*. 1994, Marín 1998). Whether the term used is a construct or a regularity is a methodological and theoretical problem rather than a personal opinion.

Without making any attempt to solve these problems of terminology, we shall use the word schema as a construct which forms part of the non-visible cognitive network of the subject and reserve the term conception to refer to the students' responses, which should have some degree of regularity that is constructed by an inductive process by the science expert as an observable manifestation of the students' cognitive baggage (Brumby 1979, Nussbaum and Sharoni-Dagan 1983, Terry and Jones 1986, Brown 1989, among others).

General characteristics of conceptions

We mentioned above that both SC and PC, for different reasons, studied students' knowledge, the former obtaining the general characteristics of their conceptions based on their responses and the latter the general characteristics of cognition. For this reason, the general characteristics of SC conceptions should not be very different from those deduced from Piagetian theory.

SC has provided much information on students' conceptions and has defined their general characteristics, so that while conceptions refer to a specific knowledge of a concrete academic content, the characteristics refer to the subject's cognitive tendencies. These general characteristics have been defined by a procedure, which is to a greater or less extent inductive from the most frequent tendencies and regularities observed in students' replies and found in the different phenomenologies of the sciences (for example, Driver 1986; 1988, Driver *et al*. 1985, Osborne and Freyberg 1985, Pozo and Carretero 1987, Pozo *et al*. 1991).

Without entering into detail, since the list of the general characteristics of conceptions has been published in different places (Driver 1986, Gunstone and Watts 1985, Hierrezuelo and Montero 1991, Pozo *et al*. 1992), we shall mention the most relevant:

(1) It is usually said that conceptions are *active schemes* which set dynamically as 'ways of seeing' reality and which in turn are used to acquire academic knowledge (Driver 1988). Moreover, many of the students' ideas are deep rooted and cannot be easily changed by instruction (Hierrezuelo and Montero 1991, Oliva 1996).

(2) Spontaneous ideas are shared by people of *different ages and cultures*. For example, when the same questionnaire on situations in mechanics was given to students in England, Kenya and Portugal, the replies were similar (Gunstone and Watts 1985). The refusal to believe that a vacuum can exist in matter has been recorded in Israeli (Novick and Nussbaum 1978), American (Novick and Nussbaum 1981), English (Brook *et al*. 1984) Spanish (Llorens 1988, Benarroch 1989), German (Pfundt 1981), Scottish (Dow *et al*. 1978) and New Zealand (Osborne and Schollum 1983) teenagers. Several studies have demonstrated that this idea can persist in university students (Novick and Nussbaum 1981).

(3) Conceptions are *coherent* for the person that has them and help him/her explain daily phenomena. For example, students normally associate force with constant movement (Brown 1989, Gamble 1989, Watts and Zylbersztajn 1981), a notion of little scientific value but which is well adapted to what they see. Thus, it may seem unreasonable to think that sugar dissolved in water itself becomes water; however, this may not seem such a wild idea when you take into account that children use the word water to describe any transparent liquid.

(4) Frequently students give a meaning to a concept and then use the same concept with a different meaning, without there seeming to be a contradiction in their minds. This suggests that *students' ideas are diffuse or poorly differentiated*, which is not at odds with the fact that the conceptions are coherent for the subject, bearing in mind that they are very specific and therefore change with the context. For example, in children's minds,

weight is frequently associated with aspects of volume, density and pressure (Driver 1988).

(5) *Spontaneous notions are dominated by perception.* Indeed, the figurative aspect of the problem posed influences the determination of the direction and intensity of the action produced. For example, it is necessary to exert more force to retain a car near the top of a mountain slope than when it is only half way up (Watts and Zylbersztajn 1981), or it is usually thought that a block exerts more horizontal force when it weights more (Maloney 1984) and that a system made up of two equal weights joined by a string and suspended by a pulley, is not balanced if the weights are not on the same level (Viennot 1979). Other examples include two people pulling on a rope in opposite directions in a tug-of-war contest. Supposing that there is no movement, more force is being exerted by the heavier person (Terry and Jones 1986) or the one who seems to be winning (Watts and Zylberstajn 1981). This rule also appears to extend to other fields of science. Thus, light only exists when its effects are observable (Guesne 1985), or gases when they are colored (Séré 1985).

(6) *Conceptions are marked by spatial and temporal causal lineal reasoning.* In other words, the cause of any phenomenon must be physically nearby or even in contact with the effect produced (spatial causality) and to have occurred only moments before (temporal causality) (Pozo *et al.* 1991). Thus, it is difficult for students to appreciate forces acting at a distance, as long as they consider as 'true' forces only those which are in contact (Hierrezulo and Montero 1991).

(7) Students generally evaluate the transformations produced by various interacting causes according to one *preferred direction*, or give priority to one of the causes, generally the most visible. As a consequence, it is difficult to appreciate the reversibility of a process. For example, a student is capable of recognizing the force exerted by a person on the earth, but not by the earth on that person (Terry and Jones 1986). It is also much easier for them to appreciate the reason for the change from solid to liquid than liquid to solid (Driver 1988).

(8) *Situations in which there is no perceptible effect do not require causes to be explained.* Put another way, students tend to explain changes, not states. Indeed, students have difficulty in detecting the forces acting in static situations (Gilbert *et al.* 1982). For example, there is no force acting on a body lying on a table, except perhaps, the force of weight (Clement 1982). Likewise, in their understanding of chemical phenomena, students look for explanations of apparent changes not at the initial and final stages, which prevent them from understanding concepts such as chemical reactions (Andersson 1986).

General characteristics of conceptions with PC

Having established the general characteristics of conceptions as defined from an SC viewpoint, we shall now attempt to ascertain whether they are referred to in PC, if so, we shall try to explain how they are referred to and the role they play in the theory. The order given to the characteristics in the previous section is maintained to make understanding easier.

(a) The content of (1) above is strongly reflected in the affirmations of PC with regards to the construct of *schema*. When the subject perceives something his/her perception is assimilated to a schema or structure of varying degrees of complexity and it is this schema which gives meaning to what is perceived or conceived (Piaget 1980: 7). The problem for genetic epistemology lies in determining how the step from simple knowledge to more complex knowledge is made (Piaget 1974: 74) and consequently

> absolute beginnings are never observed in the course of development and that which is new proceeds from progressive differences, or from gradual coordinations, or from both at once. (Piaget, 1977a: 39)

From this Piagetian standpoint, a schema developed at a certain level will always be an 'alternative' of that constructed at the following level and in this sense there will always be different levels of 'alternative schemas' with respect to scientifically accepted notions. It is clear then that the construct schema is coherently integrated in Piagetian theory, which explains the cognitive mechanisms which the subject uses to amplify his/her capacity to assimilate and how the schema evolves to higher levels by means of a double mechanism of assimilation and accommodation (Piaget 1978: 9).

Many of the conceptions described in SC appear in PC as a consequence of the subject not having the schemas necessary for assimilating new data, which are deformed so that they can be integrated with existing schemas. This is an example of what Criscuolo (1987) denominates per α conduct, that is the deformation of the observable in the process of assimilation by an inadequate scheme (also see Piaget and Garcia 1973: 24).

(b) The emphasis which genetic epistemology gives to schemas of action as an initial source of meaning (Piaget 1977a) provides a plausible explanation of the cross-cultural character of conceptions. Indeed, many schemas, especially mechanical ones, are first generated by an individual's reaction with the physical environment. These schemas then serve as an assimilating base to give meaning to new data reaching the individual from his/her cultural and social environment, the data at the same time enriching and making more complex the individual schemas (Piaget and García 1973). The similarity of different cultural groups' physical reality would then explain why conceptions, at least those in the different fields of science, show analogies. Gravity, the actions or efforts needed to cut, break or bend objects according to their consistency, inertial reactions, etc. all respond to natural laws and must be the same for everybody.

(c) The third characteristic referred to the *coherence of conceptions* when evaluated in light of the general characteristics of the student's thought. For Piaget, the individual's cognitive structure is not reorganized through the juxtaposition of elements. Rather, they are interrelated and the properties of the whole are different form those of the parts (Piaget 1974: 18). Although new elements are constantly integrated, the structure maintains its stability through continuous self-regulation (Piaget 1974: 18). Indeed, assimilation is impossible when the new information is too novel. New data are integrated because they are familiar and similar to those already in the structure, thus ensuring a certain coherence between the parts making up the structure and that the schemas do not lose their previous assimilating capacity (Piaget 1978: 9). It follows that conceptions which are a rational expression of the student's though process cannot be incoherent with respect to the other ideas generated in the cognitive structure (Vosniadou 1994).

(d) The *absence of differentiation in conceptions* held by students frequently appears in a Piagetian context with a similar meaning to that in SC. Look at the following examples:

(i) At the initial preoperational level (IA), the notion of 'force' is a spatial-temporal action of pushing, which cannot yet be assimilated into the action of physical magnitude, since it continues to be considered essentially psychomorphic (Piaget and García 1973: 68). It is not until the advanced preoperational level (IB) is reached that force becomes a cause of movement (Piaget and García 1973: 69).

(ii) Weight, when it is not differentiated from mass, is sometimes considered to be connected with subjective force and sometimes as a quantity. Subsequent disassociation and integration of both concepts only follows the acquisition of certain notions of space (Piaget and García 1973: 109).

It is not difficult to explain these characteristics using the conceptual framework of genetic epistemology. If we bear in mind that preoperative notions are centred in the undifferentiated subject-object action (Piaget and Inhelder 1984: 98), it can be understood why many conceptions which have all the characteristics typical of preoperational thought (figurative-dependent, contiguous causality, static, etc.) contain various undifferentiated academic concepts.

It can be seen that both the lack of differentiation and the evolutive treatment which they receive lead to a more precise and suitable understanding. Indeed, by clearly marking out the genesis of knowledge, a series of decentring is observed which tends to be closely linked with successive differentiations (Piaget and Inhelder 1984: 98-99). Hence, we can distinguish one type of differentiation in each stage of development according to the type of decentring produced. At the sensory-motory level, centring is inherent in the body itself. Later, with the development of the semiotic function, centring is established on the action itself; at the end of the preoperational level decentring is established between concepts or conceptualized actions (Piaget 1977a: 33); a new decentring takes place when actions are abstracted from their relation with objects and then become reversible at the level of concrete operations and, finally, at the formal level use hypothesis and not only proposals arrived at empirically (Piaget 1977: 58).

(e) The influence of the figurative aspect of the task in the individual's answers has been tackled by Piaget, within a wider evolutionary perspective, as a preoperatory characteristic of thought.

Piaget considered perception, imitation and mental image as 'figurative' instruments of thinking (see, for example Piaget 1980: 44). These only permit a static assimilation of phenomena, but not the dynamic process. One has to wait for mental operations to appear for the static images of the preoperational level to acquire mobility and for anticipatory images to be possible (Piaget 1980: 46). The best Piagetian experiments, for example, Piaget and Szeminska 1982: 19-41 and 94-106 (eight blue and eight red counters facing each other in line and pouring of liquids); Piaget and Inhelder 1971: 33-108 (conservation of the quality of matter, weight and volume), have repeatedly shown that a cognitive structure incapable of operatory reversibility is at the mercy of the figurative dictates of the data, with cognitive phenomena such as centring (emphasizing one figurative factor rather than another) or static representation (considering only the initial and final states and not the transformation) appearing.

The above lines of argument explain why the figurative aspect of the data in a task prevails in the individual's answer and what is more important, why the cognitive prerequisites are laid down which enable the individual to begin to structure the data instead of falling victim to this mistaken perception.

(f) The problem of causality is treated in an evolutive way, so that the causal characteristics mentioned above (6), (7) and (8) an others besides, appear in one or more specific phases of the evolutive development. Thus, the spatial continuity of causality (6) appears at the level of concrete operations (Piaget *et al*. 1972: 7-98), which is why in a previous stage it would not be right to present the problem in this way since the individual's reactions are unpredictable and differ of the possible cause-effect relationships.

The absence of reciprocity in actions (7) and the fact that students tend to explain changes rather than static situations, are characteristics both of the pre-operatory level and of concrete operations. At the formal level, causality simply subordinates the states and transformations into one single total system, which includes the virtual and the real and confers on the virtual a physical reality of the same nature as the real (Piaget 1975: 56-73).

Not to consider it necessary to give causal reasons in static situations or, what amounts to the same thing, say that *there is only force when there is movement* (8) appears in Piagetian studies as a consequence of the non-differentiations of the schemas of action of pre-operational thought (Piaget *et al*. 1972: 63; 89).

Other characteristics, such as the absence of additivity at the pre-operational level and beginning of concrete operations (Piaget *et al*. 1972: 15; 62), the difficulty of seeing various causes acting simultaneously but, instead, seeing them as successive (Piaget *et al*. 1972: 89), the regressions in subjects at the concrete level to establish causal relations when they are beginning to perceive the dynamic character of weight (Piaget *et al*. 1972: 21), the differentiation between force and movement at the end of concrete operations (Piaget and García 1973: 62) and others appear frequently in Piaget's work, though not in SC (Marín and Benarroch 1994).

In addition, the characteristics relating to causality, far from being unconnected can be integrated and explained within the framework of PC, since reference is made to the causal explanations of the individual based on the progressive differentiation between causality and the operations (Piaget and García 1973: 142) and thus in the increasing possibility of attributing mental operations more comfortably to the causal behaviour of objects, as a form of assimilating, understanding and explaining the said behaviour (Piaget and García 1973: 26; 141).

Thus, at the pre-operational level, in which

> 'there exists a relative non-differentiation between causal and logical relations' the irreversible actions of the individual applied to objects lead on the one hand 'to the lack of reciprocity in relations' and on the other 'to the psychomorphic character of the explanations' (Piaget and García 1973: 146-147).

Later, at the concrete operations level, incomplete groups of operations are formed which, since they are attributed to objects, form a causality of

> sequences in a certain way unilinear in time (successive sequences without multiple or simultaneous interactions) and in space (privileged directions without vectorial compositions between unequal directions of force) (Piaget and García 1973: 148).

Finally, at the form level,

> the operations are sufficiently detached from their content . . . , and their attributions to objects give causality decisive progress in all the areas which were studied . . . thought begins to seem functionally like scientific though (Piaget and García 1973: 149).

Conclusions: points where SC and PC converge

The most obvious conclusion is that the general characteristics of conceptions, as defined by SC, can be lodged within the framework of PC. This result may seem surprising since the empirical data are treated very differently and SC's rejection of PC suggested that two distinct and settled points of view were involved. On the other hand, the fact that there is common ground perhaps should not be so surprising since it is the same reality that is being described: the knowledge of the learner. It would have been more surprising not to find anything in common. This common ground shared by both SC and PC opens up new possibilities for joint action by both groups to improve syllabus design and teaching methodology. In the search for points in common between both tendencies, the capacity of Piaget's theory to explain a large number of the general characteristics of conceptions has been demonstrated:

- Many of the students' conceptions about the concepts and laws of mechanics (Hierrezuelo and Montero 1991, Jiménez Gómez *et al*. 1997) can be interpreted as the consequence of Piaget's schemas of action. This makes it possible to go beyond the descriptive character of the studies on SC conceptions. Some studies, indeed, have demonstrated that students possess conceptions that can be interpreted as the consequences of a deformation of the process of assimilation due to the use of an inappropriate schema (Criscuolo 1987). Others reinterpret works on conceptions using the notion of cognitive level and operational schema (see Monk 1991) or interpret conceptions, including tasks in the same questionnaire directed both at determining aspects of specific knowledge (conceptions) and general knowledge (operational schemas) (Stavy 1990).
- The coherence of conceptions can be explained by Piaget's theory of equilibration.
- The decentring processes, which are characteristic of the genesis of Piagetian schemas explain the different modalities of indifferentiation of conceptions.
- The subject's thoughts are tricked by the perceived aspects of the task when the schemas used to reply have not achieved reversibility.

Indeed, the Piagetian framework can offer a theoretical context which goes even further than the mere description of conceptions. However, to describe conceptions as schemas of knowledge is not a problem of terminology but of methological rigour (see Benarroch 1998).

SC (Driver 1988, Driver *et al*. 1994) has shown the *need to understand the evolutionary sequence of children's thinking* to elucidate whether students' net results, which appear similar at different ages or after the teaching and learning processes, are due to a methodological problem or, on the contrary, may be due to obscuring reasoning which is becoming more sophisticated. Genetic epistemology, with such relevant constructs for understanding cognitive development as egocentrism, decentring, reversibility, transformation capacity, etc. might offer substantial help in describing and interpreting the evolving sequence of children's and adolescents' thinking. The present authors have published two papers following, among others, this suggestion (Marín 1994, Benarroch 1998). Other characteristics, besides being explained, can be lodged in the individual's evolutive development, where they take on a clearer meaning than if presented in an isolated way. Here are some examples:

- Thought depends on the figurative aspect of the task when the subject does not have the necessary operational schemas. The cognitive level is a determining factor for foreseeing the pupil's reactions (Shayer and Adey 1984, Pozo *et al*. 1991, Niaz 1991, Lawson 1993).
- Causal characteristics as obtained form the catalogue of conceptions can be distributed through the different stages of evolutive development. For example, it is usual for the pre-operational reactions of the subject to follow unforeseeable directions which do not fit in the frame of cause and effect relations, it would be more appropriate to speak of spatial continuity at a level of concrete operations (Piaget *et al*. 1972: 7-98).

If we set the general characteristics of conceptions in the relevant stage of evolutive development, relate them with relevant factors of this development, such as decentring, reversibility of schemas, transformational capacity etc. and differentiate, if necessary, different modalities of a given characteristic, our knowledge of the pupil's thinking will be that much greater and will be able to take more precise steps in teaching situations. Moreover, evaluating the student's conceptions at the adequate cognitive level will be 'fairer' than basing this evaluation on scientific or academic knowledge, especially if it is remembered that the subject in each phase of his/her evolutive development presents certain limitations and capacities which are very different to when scientific procedures are used (Piaget 1977a). Too high a bar will simply divide a sample into those who can jump over it and those who can't, while bars placed at different heights and which respect the students' capacities will lead to more precise divisions and lead to better teaching.

Such a collaboration between SC and PC must not tempt us to forget the problems of PC, such as 'décalage' and others (Vuyk 1985, Pozo *et al*. 1991). However, far from simply rejecting one point of view, we think that the operational level can be linked with the contex and physical variables of the task (Marín 1994), which would take the relevant Piagetian constructs to describe evolutive development and thus improve science teaching.

Although most of the suggestions made in the present paper represent contributions of PC to SC, there is no doubt that if further conciliatory efforts were made, other bridges and links would be found by which SC could enrich the view of PC. Whatever the case our aim is conciliatory and we do not pretend to affirm the superiority of one trend or the other. Thus, based on the above conclusions we can indicate that:

- Conceptions firmly established in the subject's cognitive structure (Strike and Posner 1990) may be assimilated in certain Piagetian schemas so that the equilibration model proposed by Piaget (1978) would provide precise didactic suggestions for teaching (Marín 1994).
- The extensive catalogue of SC on students' conceptions for a variety of phenomenologies provides much of the specific content which is lacking in Piagetian theory and which would make its application to science teaching more useful and effective.

Many authors have opted for this conciliation between SC and PC (for example, Aliberas *et al*. 1989, López Rupérez 1990, Perales 1992, Pozo *et al*. 1992, among others) and in light of this, (Matthews 1994, Solomon 1994, Duschl 1994, Gilbert 1995, Ritchie *et al*. 1997, Kelly 1997) perhaps now is the moment to continue with this tendency.

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