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SOCIOCOGNITIVE CONFLICT PROCESSES IN SCIENCE LEARNING: BENEFITS AND LIMITS

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Abstract. *The present paper focuses on instructional treatment of students' conceptions about floating and sinking through sociocognitive conflict processes. In this direction a study was prepared including the detection of students' conceptions of floating and sinking as well as the design, implementation and evaluation of teaching sequences implemented in 14 year-old students in Greece. Data collection was carried out through interviews and qualitative analysis of the students' writings and talk during the teaching sequences. The analysis of the students' writings and talk brought out their different reactions to sociocognitive conflict processes as well as the different learning outcomes of those processes as regards the change and construction of new conceptions.*
Keywords: *sociocognitive conflict, science learning, floating, sinking.*

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Introduction

Students have formed conceptions of science concepts and phenomena, which in most cases differ from the views of scientific knowledge and its school version (Driver, Guesne & Tiberghien, 1985; Pfundt & Duit, 1994). The cognitive conflict has been used as a teaching strategy aiming to change the students' conceptions, while its positive effects have been proved by a significant number of studies (Druyan, 1997; Hashweh, 1986; Hewson & Hewson, 1984; Kwon, 1997; Lee, 1998; Niaz, 1995; Posner, Strike, Hewson, & Gertzog, 1982; Stavy & Berkovitz, 1980; Thorley & Treagust, 1989). Within the framework of this strategy, the conceptions constructed by a student are either confuted or challenged –usually by presenting discrepant experimental events– so that a cognitive disorder or destabilisation is created and, as a result, the conceptions are either abandoned or replaced by other ones (Hewson & Hewson, 1984).

However, some researchers support that the presentation of discrepant events to the students does not necessarily lead them to cognitive conflict processes and to conceptual change (Chan, Burtis & Bereiter, 1997; Chinn & Brewer, 1998; Dreyfus, Jungwirth & Eliovitch, 1990; Limón, 2001; Mason, 2001; Tirosh, Stavy & Cohen, 1998). Additionally, it is often realised that the students are not capable of achieving a meaningful conflict or contradict their conceptions even when they experience situations involving a conflict (Dreyfus, Jungwirth & Eliovitch, 1990; Kang, Scharmann & Noh, 2004). The discrepancy between the student's initial conceptions and the result of an experiment does not automatically provoke a cognitive conflict (Chinn & Brewer, 1998; Tirosh, Stavy & Cohen, 1998; Mason, 2001), while the farther the students' conception from

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the pursued conception, the greater the possibility of avoiding the conflict (Limón, 2001).

Researches delving into the students' answers, when they encounter data different from their current conceptions (discrepant events), have been carried out in science education research (Chinn & Brewer, 1998; Gorsky & Finegold, 1994; Kang, Scharmann & Noh, 2004; Mason, 2001). The researches proposed a classification of individuals' reactions to discrepant events. For example, Chinn and Brewer (1998) proposed seven types of responses to anomalous data: (a) ignore the anomalous data, (b) reject the data, (c) exclude the data from the domain of theory A, (d) hold the data in abeyance, (e) reinterpret the data while holding theory A, (f) reinterpret the data and make peripheral changes to theory A and (g) accept the data and change theory A, possibly in favour for theory B.

It should be noted that as regards the learning process the use of sociocognitive conflicts may be more effective (Ames & Murray, 1982; Doise & Mugny, 1984; Doise, Mugny & Perez, 1998). According to this strategy, learning is considered a process of personal construction by means of cognitive conflicts of social origin (Doise & Mugny, 1984). The sociocognitive conflict tries to contrast two or more thoughts, while the communicative contrast among the participants dominates. The students realise that there are more approaches apart from their view, while at the same time the sociocognitive conflict process provides them with new information, thus making them capable of giving alternative answers (Foulin & Mouchon, 1998). Moreover, this conflict, as a disagreement among students of similar mental possibilities over the solution to a problem or the judgement on a cognitive issue, constitutes a mechanism through which the student's thought is led to a higher form of counterbalance (Doise & Mugny, 1984). After all, sociocognitive conflicts allow the students to become conscious of the relativity and the weaknesses of their conceptions as well as acquire techniques for communicating and negotiating on the knowledge they possess.

Thus far, in Science Education Research there have been limited attempts to investigate sociocognitive conflict processes with respect to the change in students' conceptions (Astolfi & Peterfalvi, 1997; Johsua & Dupin, 1988; Ravanis, Papamichael & Koulaidis, 2002; Skoumios & Hatzinikita, 2005, 2006; Trumper, 1997). It is necessary to further study the results of the processes in which the students confront discrepant events and discuss these events as well as other conceptual areas of science, as the students' opposition to discrepant experimental events is frequent during the instruction of various concepts and phenomena in the classroom, while it has been also realised that the students are very unwilling to abandon their initial conceptions.

In addition, there is another issue not systematically investigated yet, which concerns the use of sociocognitive conflicts in science teaching. This issue refers to the students' reactions to situations of sociocognitive conflict. More specifically, it is about the ways of regulating the conflict. The research carried out so far has been mainly focused on the results of sociocognitive conflict processes with respect to the changes in students' conceptions. The study of students' reactions is particularly important because they determine to a great extent the outcome of conflict processes (Doise & Mugny, 1984).

The floating and sinking of objects was chosen to be the conceptual area for the investigation of the above issues, which concern students' reactions to sociocognitive conflict processes as well as the results of those processes, due to the conceptual distance realised between the views of school knowledge and the conceptions constructed by the students before, during or after teaching (Biddulph & Osborne, 1984; Gibson, 1997; Hardy, Jonen, Möller & Stern, 2006; Smith, Carey & Wiser, 1985; Smith, Snir & Grosslight, 1997). The above research showed that the students construct the following conceptions: (a) dependence of floating or sinking of an object in a liquid on the object's shape or surface, (b) dependence of floating or sinking of an object in a liquid on the object's weight/mass, (c) dependence of floating or sinking of an object in a liquid on the object's volume, (d) dependence of floating or sinking of an object in a liquid on the liquid's volume, (e) dependence of floating or sinking of an object in a liquid on the object's density and (f) dependence of floating or sinking of an object in a liquid on the liquid's density.

The present paper aiming at the instructional treatment of students' conceptions of floating and sinking was designed with the use of sociocognitive conflict processes. In particular, the research aims to: (a) analyse students' reactions to situations of sociocognitive conflict and (b) study the effects of sociocognitive conflict processes on the development of students' conceptions.

Methodology of Research

Process

The research process followed included three stages. At first, teaching sequences based on sociocognitive conflict processes were designed (first stage). Then the designed teaching sequences were implemented in the classroom (second stage). Finally, the teaching sequences were analysed so that students' reactions to situations of sociocognitive conflict as well as their learning outcomes could be investigated (third stage).

Sample

The research sample included twenty (20) students (11 females and 9 males) of middle school in Greece (14 years old). The number of students may be considered a limitation of this study. Since, there are no expectations of gender differences in the field of alternative conceptions (Mintzes & Wandersee, 1998; Prokop, Kubiatko & Fančovičová, 2007), it is not necessary to investigate the influence of gender in students' conceptions about floating and sinking.

Before the implementation of the teaching sequences the students had been taught the concepts of mass, volume and density through traditional teaching, though without having elaborated on floating and sinking.

Methodology and tools for collecting data

The students' reactions to sociocognitive conflict processes as well as their learning outcomes were studied by designing and implementing teaching sequences in the classroom. Social constructivism was the theoretical framework for designing the teaching sequences concerning floating and sinking of objects. Social constructivism concerning science teaching and learning recognises that learning is a social activity that involves students into the construction of concepts through discussions and negotiations with their fellow students and their teachers. In the framework of social constructivism science learning is considered a process in which the students construct knowledge through both individual and social processes (Driver, Squires, Rushworth & Wood-Robinson, 1994). The students are given opportunities to examine new conceptions with the help of their fellow students and connect/relate these conceptions to their personal experience and current conceptions (McRobbie & Tobin, 1997). The students may recognise and articulate their conceptions, exchange conceptions and reflect on their conceptions and the conceptions of their fellow students and, if necessary, reorganise the conceptions and negotiate the knowledge they have shared with the rest of their fellow students (Prawat, 1993).

The teaching situations concerning floating and sinking of objects were formed on the basis of the above views of social constructivism and included situations of sociocognitive conflict. They were designed according to the three following steps: (a) determination of the pursued objective, (b) clarification of differences between the pursued objective and students' conceptions as well as determination of displacement steps and (c) design of teaching situations – layout of worksheets.

Step 1: Determination of the pursued objective

On the basis of students' conceptions of floating and sinking and the knowledge they have been taught according to their curriculum (i.e. mass, volume, object's density), the following objective, as pursued by the teaching sequences, was formed: dependence of floating or sinking of an object in a liquid on the relation between the densities of the object and the liquid. More specifically, if the object's density is higher than the liquid's density, then the object sinks, while if the object's density is lower than the liquid's density, the object floats.

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Step 2: Differences between the pursued objective and students' conceptions

In order to predict or explain floating and sinking of objects the students focus on only one factor of the system examined (i.e. the object's mass) and determine floating and sinking of an object only according to this factor. Thus, for example, if an object has a large mass, as said by the students, it will sink. Therefore, students' conceptions about floating and sinking of objects refer to a general characteristic of students' conceptions: linear causal reasoning (Driver, Guesne & Tiberghien, 1985). Conversely, according to the pursued objective, floating and sinking of an object is defined by the combination of two factors, namely the density of the object and the density of the liquid. This pursued objective refers to another type of reasoning, which Perkins and Grotzer (2005) define as relational causal reasoning. According to the latter, it is the relation between two factors that determines a result rather than a sole factor. As regards floating and sinking of objects, the relation between the densities of the object and the liquid determines whether the object floats or sinks in the liquid.

Step 3: Teaching situations

The design of teaching situations is based on the analysis of Step 2. The designed teaching situations aim at: (a) the emergence and temporary enforcement of students' conceptions, (b) the "destabilisation" of students' conceptions and (c) the gradual construction of conceptions, on the side of the students, in the direction of the pursued objective. A total of 8 learning situations were designed.

As regards the structure of teaching situations, they include the following parts:

- Part 1 (brainstorming): Aiming at the emergence of the conceptions the students have and use with respect to the flotation/sinking of objects a problem is posed to the students.
- Part 2 (predictions – explanations): Although the students are divided in groups, they work individually and answer by writing the questions of the problem on their worksheets.
- Part 3 (realisation of disagreements): A discussion is held among the students of each group, aiming at their realising the disagreements they have with each other.
- Part 4 (experimentation in order to verify their predictions): The students perform experiments in order to verify their predictions.
- Part 5 (temporary enforcement of conceptions): The result of some experiments is in the direction of students' conceptions and, consequently, the latter are enforced. In this case, the students are encouraged to express and support their conceptions.
- Part 6 ("destabilisation" of students' conceptions): The result of some experiments is in the direction of the pursued objective and, consequently, the students' conceptions may be destabilised. In this case, the students are quite likely to accept and incorporate in their mode of thinking another conception proposed by their fellow students or the teacher.
- Part 7 (construction of conceptions): A discussion is held among the students of each group, aiming at changing the students' conceptions in the direction of the pursued objective.

As regards the teacher's role during teaching sequences, the teacher is more or less an intervener, a facilitator, an organiser and probably the orchestrator of the teaching sequences. At the same time, the teacher aims to support the students in the process for constructing conceptions in the direction of the pursued objective. As Pintrich (1999) says: "it is not useful for teachers to create tasks that increase the opportunities for cognitive conflict and then leave students entirely to their own devices to resolve the conflict. Students must be assisted in their learning how to resolve cognitive conflict through both modeling and scaffolding" (p. 36). This means that the teacher's indirect recommendations aim to introduce the students into a cognitive context with the help of suggestions related to their conceptions as well as with ideas and hypotheses discrepant to their conceptions, which have been proposed by various students; at the same time the teacher refers to initial students' conceptions or introduces a hypothesis or remark the students do not examine by themselves. This kind of instructional support seems to produce significantly better learning outcomes than the case when the students are left alone to interact by exchanging ideas in order to change their conceptions (Hardy, Jonen, Möller & Stern, 2006).

Data analysis

The elaboration of the teaching sequences was carried out through qualitative analysis of the students' writings and talk throughout the teaching sequences.

The students' reactions to situations of sociocognitive conflict were classified into categories according to whether the students supported their conceptions, which they considered the only correct ones, or they took into account the conceptions of their fellow students while trying to examine the correctness of both their conceptions and their fellow students' conceptions.

The learning outcomes of sociocognitive conflict processes concerning the change of students' conceptions were grouped according to whether the students (a) do not construct any new conceptions, in which case they either express their initial conceptions or accept new conceptions without incorporating them in their mode of thinking, though or (b) construct conceptions in the direction of the pursued objective.

Results of Research

The presentation of the results of the present paper is articulated around the following axes: (a) students' reactions to situations of sociocognitive conflict and (b) effect of situations of sociocognitive conflict on the development of students' conceptions.

Students' reactions to situations of sociocognitive conflict

The analysis of students' writings and talk showed that their reactions to situations of sociocognitive conflict may be classified into the five following categories: (a) the students support the correctness of their conception, (b) the students manifest the incorrectness of the conception of one or more fellow students, (c) the students re-elaborate on the teaching situation aiming at its better understanding, (d) the students re-examine their conceptions and their fellow students' conceptions and (e) the students determine the limits of correctness of their and their fellow students' conceptions.

(a) The students support the correctness of their conception

This category includes the students who, despite the different conceptions constructed by some of their peers, continue trying to support their initial conception, which consider the only correct (i.e. *"in the water contained in the pot the dense and big objects sink. I am sure of what I'm saying and you cannot persuade me whatever you say", "even if the heavy object floats, I am well aware that heavy objects sink. What I'm saying is correct."*).

(b) The students manifest the incorrectness of the conception of one or more fellow students

In this case the students try to detect mistakes in the conceptions of their fellow students when they differ from their conception and, as a result, they present their conception as the only one correct (i.e. *"I think you are wrong. It is impossible that this ball does not sink. When an object is made of metal, it is heavy and, therefore, it sinks… Your mistake is that you don't understand that heavy objects by all means sink"*).

(c) The students re-elaborate on the teaching situation aiming at its better understanding

The students take into account their fellow students' conceptions, which are different from the conceptions they construct, spend time in brainstorming and suggest that the experiment be performed again and all the steps of the teaching situation be more carefully studied so that the phenomenon under examination can be more thoroughly investigated and the role and the contribution of the parameters involved in the phenomenon can be understood (i.e. *"I don't understand it. I'd say that we should perform the entire experiment right from the start again and agree on every step. In this way, we will find which opinion is more correct"*).

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(d) The students re-examine their conceptions and their fellow students' conceptions

The students of this category try to re-examine both their own conception and their fellow students' conceptions –which are different from theirs– so that they can decide on the correctness or incorrectness of both their own conception and their fellow students' conceptions (i.e. *"We should go over each and every idea carefully. The one idea says that because the object has a high density, it should sink, while the other idea says that it is not enough to examine only the object but also the liquid in which you put it. However, the first idea cannot explain why the block of wax sinks in this liquid and floats on that. So, the second idea seems to be more correct"*).

(e) The students determine the limits of correctness of their and their fellow students' conceptions

This category includes the students who try to detect cases in which their initial conception or their fellow students' conceptions become functional as well as cases in which the conception they construct or the conceptions of their fellow students are in contrast with the experimental results before they accept a conception, which they support with the help of specific results (i.e. *"Well, the opinion that the block of wax sinks is correct when alcohol is the liquid, while it is incorrect when water is the liquid. It emerges that the liquid in which we put the object makes the difference"*).

The students included in the two first categories (the student supports the correctness of his/her conception, the student manifests the incorrectness of the conception of one or more fellow students) avoid the conflict pursued by the teacher between their initial conceptions and their fellow students' conceptions. On the other hand, the students included in the three last categories (re-elaboration of the teaching situation aiming at its better understanding, re-examination of the student's conception and fellow students' conceptions, determination of the limits of correctness of the student's conceptions and in fellow students' conceptions) are involved in conflicts.

Among the above five categories referring to students' reactions to situations of sociocognitive conflict, the fourth and the first category appear more frequently (26% and 25% of the cases respectively), followed by the fifth (19%), the third (16%) and the second category (14%).

Effects of sociocognitive conflict on the development of students' conceptions

The qualitative analysis of students' writings and talk allowed the detection of cases in which the discussions among the students either obstructed both the establishment of the conflict and the resulting change in their conception or contributed to the conceptual progress of the students and to the construction of conceptions in the direction of the pursued objective. More specifically, the following results were obtained: (a) construction of the initial conception (related to linear causal reasoning), (b) acceptance of the pursued conception (related to relational causal reasoning) without incorporating it in the student's mode of thinking, (c) "co-existence" of elements of both the initial and the pursued conception and (d) construction of the pursued conception.

(a) Construction of the initial conception (related to linear causal reasoning)

During the teaching sequences there were cases in which the students refused to accept their fellow students' conceptions and, as a result, the conflict pursued by the teacher was avoided between the students' initial conceptions and their fellow students' conceptions.

In the following fragment of a discussion among the students of a group, Vassilis, despite the fact that his fellow students express different conceptions, expresses his initial conception.

Panagiotis: You see, the big block does not sink, the small one goes down.
Maria: Yes, because the liquid in which we put them makes the difference.
Panagiotis: Right.
Vassilis: No way, heavier objects always sink. What I'm saying is right.
Maria: Should we go over it?
Vassilis: No, we don't have to. Whatever you say, you should know that if an object is heavy, it will sink.

(b) Acceptance of the pursued conception (related to relational causal reasoning) without incorporating it in the student's mode of thinking

In some cases the students accepted a conception without having actually abandoned their initial conceptions, that is, without having a personal engagement in it. Those students, while they initially used the new conception, returned to their initial conception on the occasion of studying a new situation.

For example, Stephanos initially supported that the flotation/sinking of an object in a liquid is related to the object's weight.

Stephanos: The object's weight shows if it floats or sinks in the water.

During the teaching sequences the students calculated the density of various objects and the density of liquids; they concluded that an object floats if its density is lower than the liquid's density.

Eurydiki: Its density is 0.96 and the water's is 1, that's why it floats. Do you agree?
Stephanos: Yes, I do, it floats only if its density is lower than the water's.

However, in a following teaching situation Stephanos returned to his initial conception.

Stephanos: It is light; that's why it floats.

(c) "Co-existence" of elements of both the initial and the pursued conception

The students mixed elements of their initial conception (in the direction of linear causal reasoning) and the conception they were meant to construct (pursued objective) and constructed a new "intermediate" conception, which included elements of both the initial and the pursued conception. In other words, they made a "compromise" between the two conceptions by selectively keeping some elements of each conception.

For example, Georgia initially supported that the flotation/sinking of an object in a liquid is related to the object's mass.

Georgia: Objects sink when they are heavy.

During the teaching sequences the students calculated the density of various objects and the density of liquids. They concluded that an object sinks when its density is higher than the liquid's density, while it floats when its density is lower than the liquid's density.

Georgia: Its density is higher than the water's and, as a result, it sinks.

However, in a subsequent teaching situation Georgia mixed elements of both her initial conception (dependence of the flotation or sinking of an object in a liquid on the object's mass) and the conception meant to be constructed (dependence of floating or sinking of an object in a liquid on the relation between the object's and the liquid's density) and constructed a new conception including elements of both the initial and the conception to be constructed.

Georgia: This sinks because its density is higher and, of course, because it is heavy. Heavy objects with a higher density than water sink.

(d) Construction of the pursued conception

Discussions among students, when the latter are confronted with discrepant experimental results, may lead to conflicts and the construction of new conceptions by them in the direction of the pursued objective. The students systematically construct the new conceptions across the entire range of the teaching situations under elaboration.

For example, Seva initially supported that floating/sinking of an object in a liquid is related only

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to characteristics of the object (i.e. weight, volume). In the following fragment of a discussion among students Seva changes her initial conceptions and constructs a new conception in the direction of the pursued objective.

Seva: Yes, but why does it not sink in the water, while a short time ago it sank?
Michalis: It sank because we had a different liquid.
Froso: Not only the size of the block of wax but also the kind of the liquid counts.
Seva: You mean an object may sink in a liquid while it may not sink in another liquid?
Michalis: Well, this is what confuses us.
Seva: Let me see it again. Ah, it floats on water. Let me see it on alcohol.
Froso: You see? It sinks.
Seva: Wait a moment; water's density is higher than alcohol's density.
Froso: That's why it floats on water and sinks in alcohol.
Seva: So, that's the way to examine whether an object floats or sinks. We will find the density of each object and we will compare them.

In the following teaching situations Seva systematically constructs conceptions in the direction of the pursued objective.

Seva: We should examine the density of the object and the density of the liquid and compare them. This is the only way to know if the object floats or sinks.

As regards the incidence of the above cases during the teaching sequences, according to the analysis of students' talk, although the fourth case (47%) prevails, the rest of the cases present significant percentages (25%, 16% and 12% for the first, second and third case respectively).

Discussion and Conclusion

The present paper aimed to detect and record the students' reactions when they are confronted with their fellow students' conceptions that are different from theirs. The research showed that students' reactions to sociocognitive conflict processes were not uniform but were described by variety. There were cases in which the students took seriously into account their fellow students' conceptions as well as the experimental results and (a) re-elaborated on the teaching situation and performed the experiments once again or (b) examined the correctness of both their conception and their fellow students' conceptions or (c) specified the limits of correctness of their own conception and their fellow students' conceptions. But there were also cases in which the students did not take seriously into account their fellow students' conceptions and, as a result, supported the correctness of their initial conceptions or tried to trace mistakes in their fellow students' conceptions in order to prove that theirs were the only correct conceptions.

As regards the learning outcomes of sociocognitive conflict processes with respect to the direction of the changes in students' conceptions of floating and sinking of objects, it emerged that they are also described by variety. There were students that constructed new conceptions in the direction of the pursued objective, while there were others who, despite the discrepant experimental results and the different conceptions their fellow students held, constructed conceptions in the direction of linear causal reasoning, as they had done before the teaching sequences. Finally, there were students that mixed elements of their initial conception with elements of the conception they were meant to construct and, consequently, constructed a new, "intermediate" conception with elements of both the initial conception and the conception to be constructed. These results are in line with the respective results presented in the paper by Skoumios and Hatzinikita (2005) on temperature and heat.

The above findings, as they result from the present research paper, have a considerable effect on teaching. Sociocognitive conflict processes may contribute significantly to the process for changing students' conceptions. In this direction it is necessary to: (a) design the appropriate teaching material, which will promote sociocognitive conflict processes, (b) provide opportunities as well as create teaching environments that will allow the students to construct, discuss and elaborate on their conceptions safely and (c) provide instructional support, on the side of the teacher, to the students while they are constructing their conceptions.

In the present paper the instructional treatment of students' conceptions through sociocognitive conflict processes has been exclusively seen in a cognitive context. However, the variety in students' reactions to sociocognitive conflict processes and the variety in their results raise the issue of examining the contribution of basic emotional components to both sociocognitive conflict and conceptual change processes, which, according to international bibliography, have not been researched yet (Pintrich, 1999; Pintrich, Marx & Boyle, 1993). In this direction the contribution of students' motives, attitudes and interests to the instructional treatment of students' conceptions could be studied through sociocognitive conflict processes.

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