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The Effect of Sociocognitive Conflict on Students' Dialogic Argumentation about Floating and Sinking

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Sociocognitive conflict has been used as a teaching strategy which may contribute to change students' conceptions about science concepts. The present paper aims at investigating the structure of the dialogic argumentation developed by students, when they are involved in science teaching sequence that have been designed to change their conceptions through sociocognitive conflict strategy. For this purpose, teaching sequence targeted at the elaboration of students' conceptions about floating and sinking -based on sociocognitive conflict processes- were prepared and implemented among 14 years old students. Next, the dialogues which the students had during the teaching sequence were analysed with the help of the framework for assessing the structure of the dialogic argumentation of Clark and Sampson (2008). The results of data analysis demonstrate that the sociocognitive conflict strategy promotes the structure of students' dialogic argumentation about floating and sinking.

Key Words: sociocognitive conflict, dialogic argumentation, students' conceptions, floating and sinking, science education

Introduction

Over the past two decades, an increasing number of research has focused on dialogic argumentation in school science teaching (e.g., Baker, 2003; Baker, Andriessen, Lund, van Amelsvoort, & Quignard, 2007; Boulter & Gilbert, 1995; Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002; Hogan, Nastasi & Pressley, 1999; Kelly & Duschl, 2002; Martins, Mortimer, Osborne, Tsatsarelis, & Jiménez-Aleixandre, 2001; Naylor, Keogh, & Downing, 2007; Simon, Erduran, & Osborne, 2006; von Aufschnaiter, Erduran, Osborne, & Simon, 2008; Weinberger & Fischer, 2006; Zohar & Nemet, 2002). The intense interest of the researchers in students' dialogic argumentation results from the belief that constitutes a significant element of science and science learning. Scientists engage in argumentation to develop and improve scientific knowledge (Lawson, 2003). Also, according to Driver, Asoko, Leach, Mortimer and Scott (1994), science learning does not add up to just acquiring information about the natural world, but also "learning science involves being initiated into scientific ways of knowing"

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(p.6) and experiencing with the practices adopted by the scientific community. These practices involve making claims and using arguments to assert and defend such claims, to clarify and to persuade (Andrews, Castello, & Clarke, 1993).

Dialogic argumentation occurs "when different perspectives are being examined and the purpose is to reach agreement on acceptable claims or courses of actions" (Driver, et al., 2000, p. 291). Dialogic argumentation focuses on the interactions of individuals or groups attempting to convince one another of the acceptability and validity of alternative ideas. Through dialogic argumentation students "articulate reasons for supporting a particular claim, attempt to persuade or convince their peers, express doubts, ask questions, relate alternate views, and point out what is not known" (Driver et al., 2000, p. 291), "they can reflect on their own ideas and the ideas of others, aiding them in addressing misconceptions and developing better understandings" (Cross, Taasoobshirazi, Hendricks, & Hickey, 2008, p. 839). Further, they see science as a developing, continuous process in which ideas are determined, questioned, and often changed or revised (Diehl, 2000).

Research in science education -during the last twenty five years- has shown that children and adults construct conceptions about science concepts which differ from accepted scientific ideas (Osborne & Freyberg, 1985; Pfundt & Duit, 2006; Scott, Asoko, & Driver, 1992). Many conceptions have been found to be universal; that is, the same conceptions occur consistently across diverse populations regardless of age, ability, or nationality of students. Furthermore, these conceptions are remarkably resistant to change using conventional teaching methods (Wandersee, Mintzes, & Novak, 1994). Multiple and varied sources of conceptions held by students have been identified. Such sources include parallels from history, use of intuitive rules, prior experience, use of language, and even instruction (Wandersee et al., 1994).

Conceptual change is the most significant learning model that evolved from the "conceptions movement" and posits that "learning consists of iterative interactions that take place between students' existing conceptions and their new experiences" (Kang, Scharmann, Noh, & Koh, 2005, p. 1038). Posner, Strike, Hewson and Gertzog (1982) suggested that four conditions - dissatisfaction, intelligibility, plausibility, and fruitfulness - should be met in order to replace non-scientific conceptions held by students. This inspired a number of teaching strategies to promote conceptual change. Among them, a cognitive conflict strategy has been a common strategy incorporated in most conceptual change models (Chan, Burtis, & Bereiter, 1997; Pintrich, 1999).

Cognitive conflict has often been induced by discrepant events - presenting information and/or experiences that clearly contradict students' existing conceptions. The usual cognitive conflict paradigm involves: (a) identifying students' current state of knowledge, (b) confronting students with discrepant event and (c) evaluating the degree of change between students' prior conceptions and a post-test measure after the instructional intervention (Limón, 2001). A considerable number of researches argue that cognitive conflict strategy promotes a conceptual change (e.g. Druyan, 1997; Hashweh, 1986; Hewson & Hewson, 1984; Lee, 1998; Niaz, 1995; Stavy & Berkovitz, 1980; Posner, Strike, Hewson, & Gertzog, 1982; Thorley & Treagust, 1987). However, some researchers claim that cognitive conflict strategy do not necessarily lead to conceptual change (e.g. Dekkers & Thijs, 1998; Dreyfus, Jungwirth & Eliovitch, 1990; Elizabeth & Galloway, 1996). A certain number of studies suggest that students in many cases do not necessarily arouse cognitive conflict through merely experiencing a discrepant event (e.g. Chan, Burtis, & Bereiter, 1997, Chinn & Brewer, 1998; Mason, 2001; Murray, 1983; Tirosh, Stavy, & Cohen, 1998).

In recent years, sociocognitive conflict has been used as a teaching strategy which may contribute to change students' conceptions about science concepts. 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 judgment on a cognitive issue, constitutes a mechanism through which students' thoughts are 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 strategy with respect to the change in students' conceptions (Astolfi & Peterfalvi, 1997; Baddock & Bucat, 2008; Johsua & Dupin, 1988; Ravanis, Papamichael & Koulaidis, 2002; Skoumios, 2008; Skoumios & Hatzinikita, 2005; Trumper, 1997). The effectiveness or otherwise of this approach in the level of conceptual change of students, has not been well investigated. Therefore, the didactic elaboration of students' conceptions through sociocognitive conflict is a proper framework for investigating the extent to which students' dialogic argumentation and particularly its structure is promoted during their group discussions.

The floating and sinking of objects was chosen to be the conceptual area for the investigation of the above issue, 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, 1992). The above research showed that the students construct the following conceptions: dependence of floating or sinking of an object in a liquid on the object's shape, surface, weight/mass, volume, density or on the liquid's density.

The present study investigates the effect of dialogic argumentation on the didactic elaboration of 14 year-old students' conceptions of floating and sinking using sociocognitive conflict strategy. In particular, the present paper aims at: (a) mapping the structure of students' dialogic argumentation throughout the teaching sequences and (b) investigating the contribution of the teaching sequences on the development of the structure of students' dialogic argumentation.

Assessing the Structure of Students' Dialogic Argumentation

Various attempts have been made to elaborate schemata for assessing the quality of argumentation. Most of these have relied on the framework of everyday argument developed by Toulmin (1958). Toulmin (1958) identified claims, data, warrants, backings, qualifiers and rebuttals as the essential elements of arguments. The claim is the conclusion whose merits are to be established; the data are the facts incorporated to support the claim; the warrants are the reasons that establish the connections between the data and the claim; and the backing is the theoretical assumptions on which the warrants rest. Qualifiers simply establish the boundaries of the claim and rebuttals are arguments that attempt to refute the elements of an argument.

Erduran, Simon, & Osborne (2004) collapse Toulmin's data, warrants, and backings into a single "grounds" code due to the practical difficulties of reliably differentiating among these argumentation components. According to Erduran et al. (2004), the structure of argumentation and its assessment is based on two major assumptions about what counts as quality. First, high quality arguments must contain grounds (i.e., data, warrants, or backing) to substantiate a claim because "developing rational thought is reliant on the ability to justify and defend one's beliefs" (Erduran et al., 2004, p. 926). Second, arguments that include rebuttals are "of better quality than those without, because oppositional episodes without rebuttals have the potential to continue forever with no change of mind or evaluation of the quality of the substance of an argument" (p. 927).

Recently, Clark and Sampson (2008) developed a tool to measure the structure of dialogic argumentation in science classrooms. Their classification is based on analytic frameworks developed by Toulmin (1958) and Erduran, Simon and Osborne (2004). The framework characterizes the amount of conflict or level of opposition that takes place within an episode using the hierarchy outlined in Table 1. The framework defines high-quality argumentation (oppositional level 5) as discourse that emphasizes the use of multiple rebuttals that challenge the interpretation of a phenomenon and the validity of the grounds that are used to support this interpretation. On the other hand, low-quality argumentation is either non-oppositional (oppositional level 0) or consists of only claims and counterclaims that do not attempt to challenge the validity of the other participants' interpretation of the phenomenon (oppositional level 1). Counterclaim is an assertion made by a pair of students that is different from (and does not attack) the seed claim made by another student. "This code is only assigned when a comment does not focus on any aspect of the thesis of the comment it replies to; instead it offers an entirely new interpretation of the phenomena" (Clark & Sampson, 2008, p. 299).

Table 1. The overall quality of the argumentation that takes place with in an episode determine during a hierarchy based on opposition (Clark & Sampson, 2008, p. 304)

Quality	Characteristics of the Discourse
Level 0	Non-oppositional
Level 1	Argumentation involving a simple claim versus counterclaim with no grounds or rebuttals
Level 2	Argumentation involving claims or counterclaims with grounds but no rebuttals
Level 3	Argumentation involving claims or counterclaims with grounds but only a single rebuttal that challenges the thesis of a claim
Level 4	Argumentation involving multiple rebuttals that challenge the thesis of a claim but does not include a rebuttal that challenges the grounds used to support a claim
Level 5	Argumentation involving multiple rebuttals and at least one rebuttal that challenges the grounds used to support a claim

Method

Overview of the Study Design and Participants

The research involves twenty (20) 14 year-old students (11 females and 9 males) from the same class of an urban middle school located in south-eastern Greece. The number of students may be considered a limitation of this study. The research process followed included three stages. At first, teaching sequences based on sociocognitive conflict strategy were designed (first stage). Then the designed teaching sequences were implemented in the classroom by the author (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).

The teaching situations concerning floating and sinking of objects were designed according to the three following steps: (a) determination of the intended objective (the school science knowledge to be taught), (b) clarification of differences between the intended 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 Intended 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 intended 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.

Step 2: Differences between the Intended 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 intended 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 intended 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 intended objective. A total of 8 learning situations were designed. Table 2 displays the main issue to be investigated in each teaching situation.

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

Part 1 (brainstorming): Aimed 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, aimed 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 intended 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, aimed at changing the students' conceptions in the direction of the intended objective.

For example, the main objective of the teaching situation 5 (see Appendix) is for the students to recognise the liquid's role about floating or sinking of an object. The students are given two pots (A and B) containing two different liquids (water and alcohol respectively), without knowing the kind of liquids, and two blocks of wax of different size (a small and a big). The small block will be put in the liquid of pot A, while the big one in the liquid of pot B. The students are asked to predict and explain whether the two blocks of wax will float or sink in the liquids of the two pots A and B (brainstorming). They discussed with the other pupils of their group any similarities or differences between their answers and ideas. On the basis of the students' conceptions (i.e. smaller/lighter objects float, while bigger/heavier sink), many students are expected to predict that the smaller block of wax floats on the liquid of pot A and the bigger block of wax sinks in the liquid of pot B. This prediction of the students is confirmed when the students perform the respective experiment (temporary reinforcement of conceptions). At the same time, they are asked to put down the factors that determine whether an object floats or sinks in a liquid. Then the students are asked for predictions as to whether the blocks of wax float or sink in the liquids of the two pots A and B when the big block is put in the liquid of pot A and the small block is put in the liquid of pot B. According to their previous prediction and their conceptions, the students are expected to predict that the small block

Table 2. The issues investigating the teaching situations designed with respect to the floating and sinking of objects

Number of teaching situation	Issue to be investigated
1	In search of factors determining the floating/sinking of an object
2	Role of the object's mass in the floating/sinking of an object
3	Role of the object's volume in the floating/sinking of an object
4	Role of the object's density in the floating/sinking of an object
5	Role of the liquid in the floating/sinking of an object
6	Role of the object's and water's density in the floating/sinking of an object
7	Role of the object's and alcohol's density in the floating/sinking of an object
8	Role of the object's and liquid's density in the floating/sinking of an object

floats on the liquid of pot B, while the big block sinks in the liquid of pot A. However, their prediction is confuted when the students perform the respective experiment (destabilisation of students' conceptions). Then the students are informed of the identity of the two liquids and are asked to discuss the factors determining whether an object floats or sinks in a liquid (construction of new conceptions). Finally, the students are asked to compare their answers to the above questions with those they suggested in a previous part of the teaching situation.

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 intended 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 modelling and scaffolding" (p. 36). This means that the teacher's indirect recommendations should aim to introducing 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 that the students did 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).

Reliability and Validity of the Teaching Situations

The teaching situations were reviewed by two experts who hold doctoral degrees in science education and are active in research in the field of science education. Each expert was given a brief report outlying the rationale underlying the teaching sequences and they were asked to comment on, first, the validity of this approach and, second, the extent to which the tasks were appropriate and consistent with this rationale. The two experts were also encouraged to suggest possible changes with respect to the teaching situations included in the teaching sequences. Both expert reviewers made comments on the wording of the items and the questions and they agreed on the validity of the rationale underlying the teaching sequences and the targeting between the tasks and the construct they are intended to measure. The outcome of this review process provided an indication as to the content validity of the teaching situations (Cohen, Manion, & Morisson, 2000). In the next instance, the teaching situations were given to three teachers, who have been teaching science for at least 5 years, and each was asked to comment on the appropriateness of the wording of the tasks, taking in to account the characteristics of the student population being targeted. Based on the feedback that emerged from the reviews of the expert and the science teachers, the teaching situations underwent minor amendments.

Data Collection

Before proceeding to the series of lessons, we obtained special permission from the school principal and the teacher of the class. We also provided beforehand the students concerned as well as their parents with information about the nature, the purposes, the content, the experimental activities, the expected duration and the procedures of the teaching program, and we obtained their consent. The tape-recording of students' discussions took place with the consent of both the students and their parents. Moreover, we reassured them about the confidentiality of these records.

During the implementation of the teaching sequence, the students were divided into five groups. Each of the five groups comprised four students. The research data included the group discussions held during the teaching sequence that was aimed at the elaboration of students' conceptions regarding floating and sinking. Group discussions were recorded with a high-end audio-recorder, which has been placed on each group's workbench prior to their arrival. Full transcripts were produced from the tapes and served as the data source. The students made a total of 80 episodes of discussions during the teaching sequence.

Data Analysis

In order to assess the structure of students' dialogic argumentation, the episodes of discussions proposed by the students during the lessons were analysed according to the framework proposed by Clark and Sampson (2008) for assessing the structure of students' dialogic argumentation. It should also be noted that the analysis of pupils' discussions was made by two separately working researchers. Any disagreement arising during the analysis was later resolved through discussion. Students' discussions were then classified into six categories.

The first category includes discussions which contain only claims (Level 0). The following example of pupils' discussion refers to the question of whether the flotation of an object depends on its weight. It contains only claims. As these claims don't include grounds and there are no rebuttals, the level of this pupils' discussion is classified as Level 0.

S1: The object's weight shows if it floats or sinks in the water.
S2: I agree.
S3: Yes.

The second category includes discussions containing only claims and counterclaims (Level 1). The following example of pupils' discussion refers to the question of whether the flotation of an object depends on it being heavy or light. In the beginning, it includes a claim ("*objects sink when they are heavy").* A suggestion follows, *("No, objects sink when they travel")*, which is not opposed directly in the initial claim. In addition, no reason is put forward as to why the suggestion was made. This constitutes a completely different approach to the question being discussed. It is therefore a counterclaim. Moreover, as there then follow claims without grounds, and there are no rebuttals, this particular episode of the pupils' discussion is classified as Level 1.

S5: Objects sink when they are heavy.
S6: No, objects sink when they travel.
S7: I agree with S5.
S8: And I.
S6: Okay I' m tired.

The third category includes discussions containing claims or counterclaims with grounds and no rebuttals (Level 2). In the following example there is an initial claim which includes grounds *("It floats. Its density is 0.96 and the water's is 1, that's why it floats.").* Then, after a question, there follows a claim *("Yes, I do. It floats because its density is lower than the water's.")* which is accompanied by grounds *("one is big and the other is small.").* As the pupils' argumentation contains claims with grounds, and no rebuttals, it is classified as Level 2.

S9: It floats. Its density is 0.96 and the water's is 1, that's why it floats.
S10: Do you agree?
S11: Yes, I do, it floats because its density is lower than the water's.

The fourth category includes discussions containing claims or counterclaims, with grounds and only a single rebuttal that challenges the thesis of the claim (Level 3). The following example is a claim *("It floats.")* for which there are grounds *("because it is light.")*. A pupil proposes a rebuttal which includes a claim opposing the initial claim *("No, that isn't correct. It sinks.")*. No grounds are included in this rebuttal, therefore it is a rebuttal that challenges the thesis of a claim. As a result, this discussion is classified as Level 3.

S1: It floats because it is light.
S2: Yes, I agree.
S3: No, it isn't correct. It sinks.
S4: Why?
S3: I don't know.

The fifth category includes discussions which contain multiple rebuttals, which challenge the thesis of the claim, but does not include a rebuttal which challenges the ground used to support the claim (Level 4). The following example is a claim *("The big piece will be sunk the small no")* and continues with grounds *("because it is bigger and hence, heavier. A big stone will sink")*. There follows a rebuttal which contains a claim *("I say that the big piece will not sink")* which goes against the initial claim. Moreover, within the discussion there is another rebuttal which opposes the initial claim *("I do not agree. Both the small and the big piece will sink")*. However, neither of the rebuttals is opposed in the grounds. As this part of the discussion involves a claim and rebuttals which oppose the claim and not the grounds, it is classified as Level 4.

S13: The big piece will be sunk the small no
S14: I agree because it is bigger and hence heavier. A big stone is sunk
S15: I say that the big piece will not be sunk.
S16: And I say it will not be sunk.
S15: I do not agree. Both the small and the big piece will sink.

The sixth category includes discussions which contain multiple rebuttals and at least one rebuttal that challenges the grounds used to support a claim (Level 5). In the following example, there is an initial claim *("This candle will not sink in water")* which is accompanied by grounds *("because it is not big in size")*. There follows a rebuttal which contains a claim *("I disagree. I say that it will sink if we put it into water.")* which opposes the previous claim and not the grounds. A second rebuttal follows, which includes a claim *("It will not sink")* with grounds *("not because it is small, but because its density is lower than the density of water.")* which directly opposes the grounds of the initial claim. This part of the discussion is classified as Level 5, as it contains at least one rebuttal which challenges the grounds used to support a claim.

S6: This candle will not sink in water because it is not big in size.
S7: I agree.

S5: I disagree. I say that it will sink if we put it into water.
S8: It will not sink not because it is small but because its density is lower than the density of water.
S5: Why it was before sunk?
S8: It sank because we had a different liquid. Not only the size of the block of wax but also the kind of the liquid counts.

Data analysis was carried out in two stages. The first stage involves mapping the six levels of discussions produced throughout the lessons at the level of absolute values and percentage distributions. The second stage was focused on investigating the evolution of the dialogic argumentation produced by the students throughout the lessons. More specifically, x^2 test investigated the extent to which there is a statistically significant relation between the levels of students' dialogic argumentation (Levels 0, 1, 2, 3, 4 and 5) and the teaching situations. The detection and interpretation of relation is based on the size of both chi-square and of standardised residuals (Blalock, 1987; Erickson & Nosanchuk, 1985). Thus, the size of chi-square (taking into account the degrees of freedom of the particular table) serves as a mean to detect the existence of a relation. As Blalock (1987) argues, the sum of the squares of the standardised residuals provides a good approximation of the value of chi-square for a contingency table. Furthermore, it becomes evident that cells with large standardised residuals contribute most to the size of chi-square, thus being responsible (that is to say the source) for the existence of the relation between the variables represented by the dimensions of the table. Therefore, if one establishes the existence of relations on the basis of chi-square, a very meaningful way to interpret these relations is provided by the examination of the size of standardised residuals for each cell (the standardised residual for a cell shows the standardised difference between observed and expected value for this cell) (Blalock, 1987). Moreover, except the quantitative analysis of discussions, a qualitative analysis of discussions is used to substantiate the statistical findings.

Results

The analysis of students' dialogic argumentation throughout teaching sequences that have been designed to change students' conceptions regarding floating and sinking allowed for: (a) mapping the structure of students' dialogic argumentation and (b) investigating the evolution of the structure of students' dialogic argumentation and, by extension, studying the effect of the teaching sequences on the structure of students' dialogic argumentation.

Table 3. Distribution of students' dialogic argumentation by level

Levels of dialogic argumentation	Students' discussions	
	N	N%
Level 0	21	26.2
Level 1	14	17.5
Level 2	18	22.5
Level 3	10	12.5
Level 4	7	8.8
Level 5	10	12.5

Mapping the Structure of Students' Dialogic Argumentation

Students' dialogic argumentation were classified into six categories (Levels 0, 1, 2, 3, 4, 5 see section "Data Analysis"). In particular, Table 3 shows the distribution of students' dialogic argumentation by level as regards all group discussions analysed (a total of 80 episodes of discussions). It emerges that the highest percentage of students' discussions belongs to Level 0 (26.2%). The percentage of students' discussions at Levels 1 and 2 (17.5% and 22.5% respectively) is also considerable. Finally, there seems to be a lower percentage of discussions classified in Levels 3, 4 and 5 (12.5%, 8.8% and 12.5% respectively).

Effect of Teaching Sequences on the Structure of Students' Dialogic Argumentation

The analysis of students' dialogic argumentation offered the opportunity for mapping the evolution of students' discussions throughout all teaching situations. Table 4 shows the distribution of the levels of students' dialogic argumentation from teaching situations 1, 2, 3, 4 to teaching situations 5, 6, 7, 8.

After studying Table 4 it emerges that teaching situations 1 until 4 is dominated by discussions classified in Levels 0 and 1 (45% and 22.5% respectively), while there are few discussions classified in Levels 2, 3, 4 and 5 (17.5%, 7.5%, 2.5% and 5% respectively). However, the next four teaching situations (5-8) present reduced percentages of discussions classified in Levels 0 and 1 (7.5% and 12.5% respectively) and increased percentages of discussions classified in Levels 2, 3, 4 and 5 (27.5%, 17.5%, 15.0% and 20% respectively).

In addition, there was a statistically important relation between levels 0, 1, 2, 3, 4 and 5 of students' dialogic argumentation and teaching situations (1, 2, 3, 4 and 5, 6. 7. 8) ($x^2 = 19.54$, df = 2, $p<0.0001$). This relation may be attributed to the following tendencies of the students (see Table 5):

(a) The discussions of Levels 0 and 1 tend to appear at the beginning of the teaching sequence (teaching situations 1, 2, 3, 4) rather than in the last of the teaching sequence (teaching situations 5, 6, 7, 8).

(b) The discussions of Levels 3, 4 and 5 tend to appear in the last of the teaching sequence (teaching situations 5, 6, 7. 8) rather than in the previous situations of the teaching sequence (teaching situations 1, 2, 3, 4)

Table 4. The levels of students' dialogic argumentation per teaching situations (1-4 and 5-8): frequencies (N, N%)

Levels of dialogic argumentation	Students' discussions per teaching situations 1, 2, 3, 4		Students' discussions per teaching situations 5, 6, 7, 8	
	N	N%	N	N%
Level 0	18	45.0	3	7.5
Level 1	9	22.5	5	12.5
Level 2	7	17.5	11	27.5
Level 3	3	7.5	7	17.5
Level 4	1	2.5	6	15.0
Level 5	2	5.0	8	20.0

Table 5. Frequency of the dialogic argumentation levels (0, 1, 2, 3, 4, 5) used by the pupils in the teaching situations (1, 2, 3, 4 and 5, 6, 7, 8) and corresponding standardized residuals

Teaching Situations	Levels of Dialogic Argumentation		
	Levels 0, 1	Level 2	Levels 3, 4, 5
Teaching Situations 1, 2, 3, 4	27 [2.27] +	7 [0.67] -	6 [2.04] -
Teaching Situations 5, 6, 7, 8	8 [2.27] -	11 [0.67] +	21 [2.04] +

Note: Table 5 shows the following values: (a) observed values, (b) standardised residuals (in brackets), (c) a sign (+, -) indicating whether the observed value is higher (+) or lower (-) than the expected value

To be precise, there is a "devolution" of students from Levels 0 and 1 discussions to Levels 3, 4 and 5 discussions during the lessons (from teaching situations 1, 2, 3, 4 to teaching situations 5, 6, 7, 8).

In most discussions at the beginning of the teaching sequence (teaching situations 1, 2, 3, 4), students do not include grounds for their statements (i.e., *"The block will sink"*). The students often simply state agreement and repeat the portion of the comment with which they agree (i.e., *"Right", "Yes, it will sink"*). There are few statements include grounds. In these usually the students typically explain why particular aspects of the initial claim would be true (i.e., "*It sinks, because heavier objects always sink*"). In general, these discussions tend to be relatively unsophisticated in terms of scientific discourse structures. Students tend to accept the claims of other students and move onward.

On the contrary, in most discussions at the last of the teaching sequence (teaching situations 5, 6, 7, 8), students tend to critique the statements of the other students (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"*) and use rebuttals (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"*). These discussions include many more instances of clarification and queries (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", "You mean an object may sink in a liquid while it may not sink in another liquid?", "What do mean by that?"*). In addition, there are many statements with grounds and in particular data, warrants, or backings (i.e., *"Its density is 0.96 and the water's is 1, that's why it floats", "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 data the students use their personal experiences, a laboratory activity they carried out, empirical data, views of their peers or references to the worksheets used. Students tend to build on each other's contributions in order to reach a share understanding (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 cor-*

rect"). According to Naylon, Keogh and Downing (2006), these "conversations are typically dialogical and interactive, rather than following a monological chain of reasoning" (p. 24).

Discussion and Conclusions

The present paper aimed at studying the structure of students' dialogic argumentation through a series of teaching sequences focused on the didactic elaboration of students' conceptions regarding floating and sinking. Eight teaching situations were designed based on sociocognitive conflict strategy. The teaching sequence was implemented among twenty 14 year-old students. The evaluation of its results –regarding the structure of students' dialogic argumentation– was carried out by analysing the students' group discussions during the teaching sequences, according to the framework of Clark and Sampson (2008).

The results of the analysis demonstrate that the teaching sequences focusing on the elaboration of students' conceptions about floating and sinking through sociocognitive conflict processes have a positive effect on the structure of students' dialogic argumentation. More specifically, the present paper traced the level of students' dialogic argumentation throughout the teaching sequences as well as the evolution of the structure of their dialogic argumentation during the teaching sequences.

As regards the structure of students' dialogic argumentation, it emerged that most of students' discussions are classified in Level 0, according to which the students record only claims, without accompanying them with grounds or rebuttals. Moreover, several students' discussions are classified in Level 2, according to which the students not only express claims but also accompany them with grounds. However, there are significantly fewer students' discussions classified in Levels 3, 4 and 5, with the students expressing claims, grounds and rebuttals.

The above findings are in agreement with the results of other studies which focus on secondary education students. These studies have shown that although the students are able to generate claims, they usually do not provide grounds for these claims (Jimenez-Aleixandre et al., 2000; Kelly, Druker, & Chen, 1998; Skoumios & Hatzinikita, 2008). When grounds are included as part of an argument, many students tend to rely too heavily on unsubstantiated explanations to justify their claims (Kuhn, 1991) or they simply use plausible explanations as a way to replace missing evidence (Brem & Rips, 2000). Moreover, the use of rebuttals is limited by the students in order to refute the elements of an argument that propose their fellow students (Erduran et al., 2004). The limited use of grounds and rebuttals by the students can be attributed to the fact that argumentation does not appear to be a common feature of the science classroom. A study by Newton et al. (1999) shows that with older secondary students debate and discussion occupy less than 1% of total teaching time. Mercer et al. (1999) cite a number of research studies and suggest that the use of language in the classroom is often confused, unfocused and unproductive. Solomon (1998) puts forward some reasons why science teachers tend not to use discussion and argumentation as tools for teaching and learning, including lack of skill in managing the process and uncertainty as to its value. Similarly Yip (2001) describes how the pressure of the prescribed curriculum makes teachers reluctant to allow sufficient time for reflection or debate or to alter the flow of a carefully prepared lesson. Newton et al. (1999) identify teachers' resistance to changes in pedagogy as a further factor. In their research, Simon et al. (2003) found that, during face-to-face student discussions, 32% of the oppositional episodes include clearly identifiable rebuttals while the majority of the oppositional episodes involve arguments that consist of claims with grounds but without rebuttals. In the teaching sequences about floating and sinking through sociocognitive conflict strategy, 45.8% of the oppositional episodes in this study classify as Level 3, 4 or 5 arguments. These numbers suggest that the teaching strategy followed about floating and sinking scaffold high structural levels of dialogic argumentation.

Moreover, during the teaching sequences -focusing on the didactic elaboration of students' conceptions about floating and sinking through sociocognitive conflict strategy - it was found a noticeable effect on upgrading the level of the structure of students' dialogic argumentation. In particular, there was a statistically significant differentiation between levels of students' dialogic argumentation and teaching situations. This difference is more noticeable in Levels 0, 1 and 3-5. More specifically, there was a "transition" of dialogic argumentations levels from Levels 0, 1 (first four teaching situations of the teaching sequence) to Levels 3, 4, 5 (last four teaching situations of the teaching sequence). This "transition", indicates the strong contribution of the didactic elaboration to developing students' ability to structure high quality dialogic argumentation.

The relation between levels of students' dialogic argumentation and teaching situations may be attributed to reasons connected with the teaching strategy followed and the teaching situations used. The teaching strategy followed -allowing the students to work in small groups, to express and safely elaborate their conceptions- created the necessary conditions for discussion among the students. The structure of teaching situations contributed to create contradictions among the students. The discussion among the students of each group occurring in every teaching situation, while the students were trying to support their claims and persuade their peers about their correctness with the use of data and reasoning, helped the students structure high-level dialogic argumentation. In particular, the development of the structure of dialogic argumentation during the teaching sequence based on sociocognitive conflict can be attributed to the following properties: (a) activation of students' alternative conceptions, (b) students' interaction with each other to share their initial conceptions and justify them, (c) presentation of a situation that could be explained with existing conceptions, (d) temporary enforcement of existing conceptions through students' interaction with each other to share their ideas about the situation, (e) presentation of a situation that could not be explained with existing conceptions, (c) creation of cognitive conflict with this anomalous situation, (d) the need for other conceptions to explain this anomalous situation, (e) students' interaction with each other to share their ideas about the anomalous situation and its possible solution, and (f) active construction of students' own knowledge.

This paper continues the discussion about creating effective environments to support argumentation. A common framework for encouraging students to engage in dialogic argumentation inside the classroom has focused on design activities and tasks that require students to examine and evaluate alternative interpretations of a particular phenomenon (Monk & Osborne, 1997; Osborne, et al., 2004). This type of approach provides opportunities for students to examine competing ideas, evaluate the evidence that does or does not support each perspective, and construct arguments justifying the case for one idea or another (Linn & Eylon, 2006; Osborne, et al., 2004; White & Gunstone, 1992). According to Linn & Eylon (2006) and White and Gunstone (1992) this type of instructional approach not only provides opportunities for students to evaluate alternative ideas but also encourages students to use evidence to distinguish among these ideas in a more rational way. Sociocognitive conflict strategy constitutes this type of instructional approach. Moreover, while in-class discourse typically involves only a small percentage of students, learning environment -based on sociocognitive conflict strategy- offer the possibility of supporting a much broader range of students (Skoumios & Hatzinikita, 2005). When students are exposed to alternative conceptions and conflicting views, and are put in such a state of cognitive imbalance, they are motivated to continue the discussion in order to resolve with justifications the cognitive conflict. Interaction with their peers requires students to confront any differences in each other's current understanding of a topic as well as their differing attitudes or perspectives. Then, through explaining and defending their views to their group, those conflicts can be reconciled. Thus, through discussion, they arrive at negotiated meaning (social construction of knowledge) regarding the issue at stake to replace and argue. The results of this study suggest that carefully structured learning environments based on sociocognitive conflict strategy can effectively scaffold student participation in scientific discourse.

Despite the encouraging current results, the present paper should be completed with other papers investigating the contribution of teaching sequences that have been designed to change students' conceptions regarding various concepts and phenomena of science to the structure of students' dialogic argumentation. In the long run, the effectiveness of the above teaching sequences in the structure of students' dialogic argumentation is important to investigate. Furthermore, the present paper was exclusively focused on investigating the structure of dialogic argumentation produced by the students, without examining whether the conceptual content of students' comments is compatible with science school knowledge. Therefore, it would be interesting to study the relation between the structure of students' dialogic argumentation and the conceptual content of students' comments so that it could be realised whether the students' conceptual progress is "in line with" the development of their ability to structure high-level dialogic argumentation. At last, it is considered important to investigate the contribution of the separate teaching situations to the process of students' structuring discussions so that the types of teaching situation promoting the structure of students' dialogic argumentation may be detected. Such an investigation could lead to the production of improved teaching material strongly favouring the development of students' ability to structure high-level dialogic argumentation.

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Appendix. A Teaching Situation Concerning Floating and Sinking of Objects along with its Parts and Partial Objectives

	Teaching situation 5
Brainstorming	You are given two pots A and B containing two liquids and two different blocks of wax (a small and a big). You are going to put the small block of wax in the liquid of pot A and the big block in the liquid of pot B.  Predict if the blocks float or sink in the liquids of the two pots A and B.
Predictions – explanations	Put your prediction down and give explanations.
Realisation of disagreements	Discuss your opinions with the other students of your group.
Experiment	Put the small block of wax in the liquid of pot A and the big block in the liquid of pot B.
Temporary reinforcement of conceptions	Observe if the blocks float or sink. Discuss the result of the experiment with the other students of your group. Put down the factor/s determining whether an object floats or sinks in a liquid.
Brainstorming	Predict if the blocks float or sink in the liquids of pots A and B when the big block is put in the liquid of pot A and the small block is put in the liquid of pot B.
Predictions - explanations	Put your prediction down and give explanations.
Realisation of disagreements	Discuss your opinions with the other students of your group.
Experiment	Put the big block of wax in the liquid of pot A and the small block in the liquid of pot B.
Destabilisation of students' conceptions	Observe if the blocks of wax float or sink.
Construction of conceptions	Discuss the result of the experiment with the other students of your group. Talk with your teacher about the liquids contained in the two pots A and B. According to your observations and the discussion you had with your fellow students, put down the factor/s determining whether an object floats or sinks. Compare your answer to the above question with the answer you previously gave to the same question.