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FLOATING AND SINKING OF AN OBJECT IN A LIQUID – BASED ON SOCIO-COGNITIVE CONSTRUCTIVISM

Training Materials for Students

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Theoretical Framework

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

The existence and persistence of students' alternative conceptions in science gave rise to different research efforts attempting to identify conditions that encourage or drive accommodation (e.g., Posner, Strike, Hewson, & Gertzog, 1982). Dissatisfaction with current conceptions acts as a catalyst for accommodation to occur provided that the new conception is intelligible, plausible, and fruitful. This approach tends to imply that learners behave like scientists, and that ontogenic change in an individual's learning is analogous to the nature of change in scientific paradigms, ignoring the differences and disagreements about the nature of this change among philosophers, historians, and sociologists of science. Thus, each time students encounter a discrepant event, they search for new intelligible, plausible, and fruitful constructs in an attempt to balance the existing cognitive disequilibrium. Personal construction of knowledge occurs through the interaction between the individual's knowledge schemes and his or her experiences with the environment. The primary mechanism for cognitive growth is the learner's interactions with the physical environment, while the social interactions and language do not receive primary attention. Social interactions and talk with other people are, however, seen as aiding the process of accommodation by creating cognitive dissonance. This description focuses on the psychological process of equilibration and reflects the Piagetian perspective or *the cognitive perspective* in general.

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

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

Although the relationship between social circumstances and cognition remains opaque, our approach accepts the potential contribution of both perspectives to the construction of knowledge, and attempts to investigate how carefully designed individual or classroom-based discourse supports students' conceptual growth. The attempt aims at providing students with the opportunity to be involved in experimentation and discussions, or evidence-based argumentation, for the purpose of examining how the knowledge construction process is shaped and validated by students' interactions amongst them, the teacher, and the physical environment.

The Cognitive Conflict Process Model (CCPM)

Piaget viewed learning as a process where an individual constructs his or her own meaning through cognitive processes. The main underlying assumption of constructivism is that individuals are actively involved right from birth in constructing personal meaning, that is, their own personal understanding from their experiences (Flavell & Piaget, 1963). Providing a problem-solving context for actively engaging students in the thoughtful application of knowledge is an important variable in increasing learning (McMahon, 1997). These viewpoints on learning, which are now called *cognitive constructivism*, paved the way for the emergence of the educational theory called *social constructivism* (McMahon, 1997). Vygotsky (1896 – 1934) became famous for his view on mediation as an integral part of human psychology (Vygotsky, 1978). Therefore, according to the Vygotskian perspective, learning is socially constructed, meaning that learners can, with help from adults or peers who are more advanced, master concepts and ideas that they cannot understand on their own (Sternberg & Williams, 1998).

Therefore, meaning building and learning can be considered as "idiosyncratic events," involving unique learning and propositional frameworks of the learner, in addition to varying approaches to learning and varying emotional predispositions (Novak, 2002). Conceptual change is considered a complicated and dynamic process, which is affected by a variety of factors, beyond the cognitive ones, such as, motivation, goals, and perceptions of the task (Dekkers & Thijs, 1998; Lee, Kwon, Park, Kim, Kwon, & Park, 2003). Posner, Strike, Hewson, and Gertzog (1982) suggested that, in order for accommodation to occur, the learner must experience *dissatisfaction with existing conceptions.*

The dissatisfaction with existing conceptions has long been studied under several perspectives and using a variety of alternative terms, which were used to express similar meanings to cognitive conflict, such as, disequilibrium (Piaget, 1952), cognitive dissonance (Murray, Ames, & Botvin, 1977; Dekkers & Tijs, 1998), conceptual conflict (Johnson & Johnson, 1979), socio-cognitive conflict (Bearison, Magzamen, & Filardo, 1986). Based on an extended review of the literature, Lee et al. (2003) developed their own definition of cognitive conflict:

> *Cognitive conflict is a perceptual state, where one notices the discrepancy between one's cognitive structure and environment*

> *(external information), or between the components of one's cognitive structure (i.e., one's beliefs, substructures and so on, which are in cognitive structure (p. 586).*

In order to explain cognitive conflict and its effects on science learning, Lee et al. (2003) developed the Cognitive Conflict Process Model (CCPM), which is presented in Figure 1. The CCPM is based on two assumptions. Firstly, the individuality of the learner and environmental factors affect the cognitive conflict process. Secondly, the components of the cognitive conflict strongly affect behavior. The model was developed to explain the cognitive conflict that occurs when a student is confronted with an anomalous situation, which is incompatible with his or her existing conceptions in learning science (Lee et al., 2003)

The CCPM (Lee et al., 2003) is comprised of three stages. The *preliminary stage* occurs before cognitive conflict, and represents the process during which the learner accepts a problem situation as anomalous to his existing conceptions. A problem situation is characterized as anomalous when the learner identifies it as incompatible with his/her previous conceptions, or when the learner realizes that his/ her existing conceptions are inadequate to provide explanatory frameworks for a phenomenon. The second stage is the *conflict stage*, during which the actual cognitive conflict occurs, while the third stage is the *resolution stage*.

As presented in Figure 1, the CCPM (Lee et al., 2003) begins with the learner's initial conceptions, referred to as "*belief in preconception*." These beliefs refer to the explanatory structures of the learner that are constructed through his everyday experiences and prior to the examination of the concept in the school setting. Therefore, in order for cognitive conflict to occur, the learner must have some existing conceptions or explanatory frameworks regarding the phenomenon that will be examined. These preconceptions comprise, from students' perspectives, correct explanatory frameworks. In case the learner does not have existing cognitive structures regarding a science concept, then there will be no need to refer to the CCPM (Lee et al., 2003).

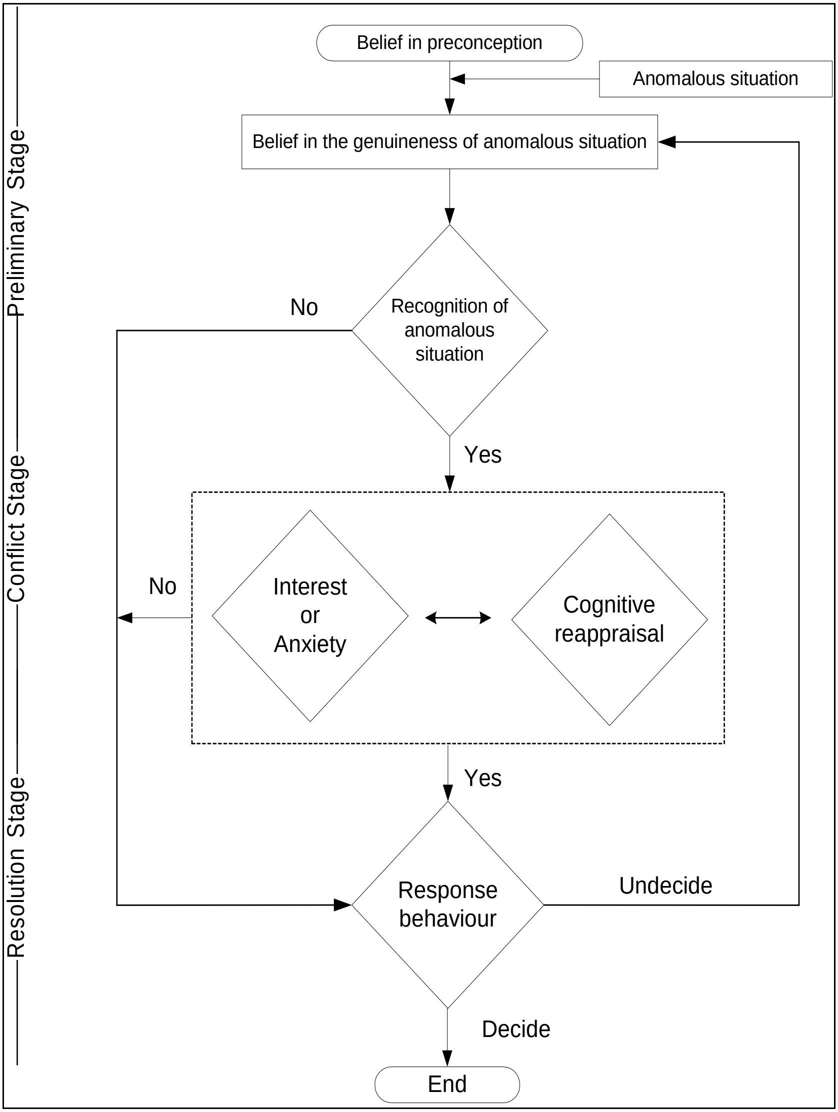

Figure 1. The Cognitive Conflict Process Model (Lee et al., 2003)

The real issue here is "How can learners' initial conceptions be identified?" Obviously, the learners should be asked and encouraged to externalize and clearly state these conceptions. The *preliminary stage* of the CCPM (Lee et al., 2003) is considered extremely important for several reasons. The learning environment or situation should not only be interesting and challenging to the learners, but it will also encourage the learners to express, in a psychologically safe environment, their genuine explanations of a phenomenon and commit themselves to these specific explanations. Subsequently, according to Figure 1, the teacher should provide the learner(s) with anomalous data (i.e., an experiment) challenging or even contradicting the learner(s)' initial conception, because the anomalous data reveal that the expressed conceptions are inadequate to provide any explanation to the problem. This situation is referred to as "*anomalous situation***.**" If the problem situation is recognized as anomalous or incompatible to the learner's existing conceptual frameworks, then the learner may eventually enter the *conflict stage*.

Obviously, if the learner does not recognize the anomalous situation, then the learner will not be cognitively engaged in solving the problem and (s)he will not face any "*cognitive disequilibrium*" that could trigger his efforts to resolve it. Consequently, the learner remains unaffected, the situation does not have any affective or cognitive implications on him/her, and does not produce any cognitive response. The arrows indicate that cognitive effort will be triggered only when the learner really accepts the genuineness of the anomalous situation, in which case (s)he will recognize the problem situation as anomalous and will enter the *conflict stage*.

As demonstrated in Figure 1, during the conflict stage, cognitive and affective factors come into play. More specifically, recognizing an anomalous situation will either arouse the learner's interest and motivation, or it will cause anxiety. Interest may trigger the learner's motivation to resolve the stage of cognitive disequilibrium and may have constructive effects concerning the cognitive reorganization of the learner's exist sting cognitive structures. Interest and motivation can encourage cognitive engagement and experimentation for resolving the cognitive disequilibrium, leading to reappraisal of the learner's initial conceptions.

On the other hand, anxiety is an emotion that may hinder the resolution of the cognitive conflict. In case anxiety is experienced, then the learner will either be discouraged, and eventually disengaged from the process of resolving the conflict, or will still proceed with cognitive reappraisal that may produce a non-appropriate response behavior, due to the feelings of anxiety or fear of the situation. *Cognitive reappraisal* that occurs under the pressure of anxiety is not likely to be as productive to the solution of the conflict as cognitive reappraisal resulting from students' motivation and interest. Evidently, cognitive reappraisal and conceptual change do not exclusively depend or are not guided by "*cold cognition*," but depend as well on the emotions that are always present during learner's engagement in any problem-solving situation, especially when the learner belongs in a social group, such as a classroom.

Lee et al. (2003) elaborated on the catalytic role of the affective domain in the process of cognitive conflict.

> *Constructive cognitive conflict can be aroused when a student recognizes an anomaly clearly, experiences strong interest and/or appropriate anxiety, and reappraises the cognitive conflict situation deeply. However, if a student does not recognize the anomaly, ignores it, or experiences a negative feeling (such as frustration or feeling threatened) instead of interest, or if she does not like to be in a conflict state, the cognitive conflict in this situation might be a negligible experience or even a destructive one (p. 590.)*

According to the CCPM (Lee et al., 2003), the learner should be consciously engaged in the process of cognitive conflict and should be kept aware of the differentiations between his/her initial and final conceptions. Having reappraised his/her ideas, the learner is subsequently able to resolve the problem or explain the discrepant phenomenon. If the learner is not able to reappraise his initial conceptions or is unaware of the differentiations between his initial and final conceptions, then (s)he remains undecided regarding the solution of the problem. Therefore, as indicated by the arrows in Figure 1, the learner reexamines the problem and is subsequently re-engaged in the conflict stage.

During the *resolution stage*, a learner attempts to resolve cognitive conflict and adjust his existing explanatory frameworks concerning the examined phenomenon. According to Lee et al. (2003), the resolution of the conflict will be expressed as an external response behavior. Response behaviors, as indicated by Lee et al. (2003), include behaviors suggested by Chinn and Brewer (1998). Examples of these behaviors are ignoring, rejection, uncertainty, exclusion, abeyance, reinterpretation, peripheral theory change, and theory change.

The implementation of the CCPM requires some competencies for science teachers (Hadjiachilleos & Valanides, 2006). These competencies concern not only the teaching practices that are implemented in the school setting, but also the professional development of teachers and the science education programs concerning pre- and in-service education. An indicative list of these competencies is presented below:

1. Science teachers must be aware of students' main alternative conceptions that are discussed in the related literature.
2. Science teachers must also be competent in diagnosing their students' alternative conceptions, using mainly qualitative approaches and formative evaluation approaches.
3. Science teachers must be able to design and develop learning environments conducive to conceptual change, taking into consideration their students' conceptions.
4. Therefore, science teachers must be able to invest on discrepant events that challenge students' existing alternative conceptions.
5. Science teachers must be able to identify discrepant events that are interesting to and engaging for the students, and are well structured, so that students can be scaffolded to realize the discrepancy between their existing conceptions and the phenomenon.
6. Science teachers must be competent to structure problem situations that can provide scaffolding towards possible solutions.
7. Science teachers must be equipped with the required abilities for correctly recognizing whether their students experience cognitive conflict or not. Even if a problem situation is designed to engage students in the process of cognitive conflict, students often fail to engage in cognitive conflict either because they do not understand the discrepancy between the problem situation and their existing conceptions, or because they do not find the problem situation interesting or plausible.
8. Science teachers must have the flexibility to differentiate a problem situation according to students' characteristics (e.g., cognitive ability, performance, gender, social and cultural background, etc) in order to enable more students to experience cognitive conflict.

9. Science teachers must be able to identify the groups of students for which the implementation of the cognitive conflict strategy is more or less effective (Zohar & Aharon-Kravetsky, 2005), depending on students‘ characteristics.
10. Science teachers must be able to provide the necessary means for their students to resolve the discrepancies between the phenomena they observe and their existing conceptions. Therefore, they must be in a position to actively support students in this process and provide cognitive and meta-cognitive scaffolding, without compromising students’ flexibility towards finding multiple solutions for a problem situation.
11. Science teachers must be able to provide valuable feedback, as to the kinds of reasoning implemented by students, and to help them develop their scientific reasoning skills.
12. Science teachers must be competent in identifying non-cognitive factors engaged in a cognitive conflict situation, and to incorporate these factors productively in the learning process. Therefore, they must conceptualize students’ learning as an effort that extends beyond cold cognition, by incorporating the affective domain towards promoting productive learning outcomes.
13. Consequently, science teachers must be able to encourage positive emotions, such as, interest and feelings of psychological safety and competence, among students when engaging them in the cognitive conflict process.
14. Accordingly, science teachers must be able to alleviate negative emotions, such as anxiety, experienced by their students during a cognitive conflict situation.
15. Science teachers must be competent in undertaking roles as facilitators and supporters, when students attempt to resolve their cognitive conflict situations.
16. Science teachers must be able to promote productive social interactions among their students, in ways promoting collaboration and shared responsibilities for the knowledge construction process, so that groups of students become real learning communities.
17. Science teachers must be able of recognizing their students’ conceptual change by identifying students‘ cognitive gains, or conceptual advancement, difference between initial and final conceptions, and must

provide opportunities for students to become aware of these differentiations.

18. Science teachers must be able to develop problem situations, where students not only will become aware of their conceptual advancement, but where they will also be challenged to implement their reappraised conceptions.
19. Science teachers must be able to provide opportunities for their students to become consciously aware of their involvement in each step of the problem-solving methodology, by incorporating continuous ongoing reflection concerning the process and outcomes of doing science through inquiry.
20. Science teachers must be competent of evaluating their own and their students' conceptions based on criteria compatible with the tentative nature of science.

This list of competencies for science teachers is not exhaustive, but constitutes useful guidelines that should be taken into consideration for both pre- and in-service training of science teachers. More specifically, professional development for science teachers should be a continuous process extending from pre-service education to the end of their professional career. Professional development programs should also provide incentives and opportunities for science teachers to be involved in a variety of professional activities, regarding not only the understanding of abstract science concepts, but also rich learning activities for improving science teachers' Pedagogical Content Knowledge (PCK) and action research skills for evaluating their own classroom teaching (Valanides, 2002; Valanides & Angeli, 2002; Valanides & Angeli, 2005; Valanides, Nicolaidou, & Eilks, 2003; Papastephanou, Valanides, & Angeli, 2005; Zion et al., 2004). Needless to mention that there is also an urgent need to encourage the integration of ICT in teaching and learning and promote the development of ICT-related PCK (Angeli & Valanides, 2005; Valanides, 2003; Valanides & Angeli, 2006; Valanides & Angeli, 2006). Regarding the issue of preparing science teachers to teach in technology-rich classrooms, in-service and pre-service training should emphasize ICT-related PCK as the form of knowledge science teachers need to become competent to teach science with ICT tools appropriate for science learning and in ways that signify *the added value* of technology for science (Valanides & Angeli, in press; Angeli, Valanides, & Bonk, 2003; Angeli & Valanides, 2004; Angeli & Valanides, 2005).

Moreover, pre- and in-service science education programs must make science teachers aware of and able to use a variety of methodological approaches in order to promote more effective learning outcomes. For example, science teachers must be able to promote learning essential science content through the perspectives and methods of inquiry (Zion et al., 2004). Therefore, they must be competent of actively investigating a phenomenon, interpreting results, and extrapolating those findings towards conclusions, which are compatible with current accepted scientific understandings. Additionally, professional development programs should encourage, support, and sustain teachers, as they implement effective science programs incorporating cognitive conflict, since the cognitive conflict approach seems to promote effective science learning for certain groups of students (Hadjiachilleos, 2007).

Additionally, pre- and in- service science education programs should provide opportunities to enable educators understand the interconnectedness between multiple domains of the subject matter, or between science and other cognitive domains (e.g., mathematics), and to enable educators to incorporate this interconnectedness in their science teaching. The problem situations implemented by science teachers should be developmentally appropriate, interesting, and relevant to students' lives, emphasize student understanding through inquiry, and be connected with other school subjects.

Therefore, in order for *Cognitive Conflict* to occur, the learner must have some existing conceptions or explanatory frameworks regarding the phenomenon which is examined. These initial beliefs in preconceptions comprise the existing explanatory frameworks of the learner. Subsequently, according to the CCPM (Lee et al., 2003), the learner encounters a problematic situation, which is contradictory to his initial beliefs or conceptions, or which proves or indicates that the existing conceptions are inadequate to provide an explanation to the problem. This problematic situation is referred to as "*anomalous situation*."

Therefore, if the problem situation is recognized as anomalous or incompatible to the learner's existing conceptual frameworks, then the learner enters the *conflict stage*, which is the stage during which cognitive conflict is experienced. In case the learner does not believe in the genuineness of the anomalous situation, then a response behavior, regarding the solution of the problem, is externalized.

During the conflict stage, a variety of cognitive and affective factors come into play, as demonstrated in Figure 1. During this stage, the learner is engaged in a process of cognitive reorganization and experiences certain feelings and emotions, which either promote or hinder learning, such as, interest and/or anxiety. The model recognizes that the role of the affective domain is influential during the process of cognitive conflict. More specifically, having recognized the discrepancy between his/her existing and the scientifically accepted conceptions, the learner experiences either interest, which promotes positive attitudes and motivates him/her to be engaged in the alleviation of the conflict, or anxiety, which hinders his/her involvement in the process.

The learner's involvement in inquiry is the means for resolving a cognitive conflict situation. Therefore, after being involved in its basic stages, such as, forming hypotheses, designing and carrying out an experiment, and making sense of the findings, the learner is actively involved in a process of *cognitive reappraisal* of his initial conceptions. According to the CCPM, the learner should be consciously engaged in the process of cognitive conflict and be well aware of the differentiations between his/her initial and final conceptions. Having reappraised his/her ideas, the learner is subsequently able to resolve the problem or explain the discrepant phenomenon. If the learner is not able to reappraise his initial conceptions, or if the learner is not aware of the differentiations between his initial and final conceptions, despite the fact that he has recognized a problem situation as anomalous, the learner is subsequently re-engaged in the four components of the cognitive conflict process. If these four components are adequately experienced, then the learner expresses a response behavior, during which he/she externalizes his decisions regarding the solution of the anomalous situation.

In a recent study, Lee et al. (2003) also developed an instrument for measuring cognitive conflict in secondary-level science classes that is based on the CCPM. Their instrument is called Cognitive Conflict Levels Test (CCLT) and aims at measuring the degree to which students are engaged in the four main constructs of cognitive conflict, namely, recognition of anomaly, interest, anxiety, and reappraisal of the cognitive conflict. CCLT consists of twelve general-type statements, presented in Table 1, and subjects are called upon demonstrating their degree of agreement to each statement, using a 5-point Likert scale.

Table 1
Cognitive Conflict Levels Test (CCLT)

Recognition of Anomaly	
1	When you saw the results, did you have any doubts about them?
2	When you saw the result, were you surprised by it?
3	Did the difference between the result and your expectation made you feel strange?
Interest	
4	Did you find the result of the experiment interesting?
5	Since you saw the result, have you been curious about it? Is there something you would like to investigate further?
6	Did the result of the experiment attract your attention?
Anxiety	
7	Did the result of the experiment confuse you?
8	Since you cannot solve the problem, are you in agony?
9	As you cannot understand the reason for the result, do you feel depressed?
Reappraisal of the Cognitive Conflict Situation	
10	Would you like to ascertain further whether your idea is incorrect or not?
11	Do you need to think the reason for the result a little longer?
12	Do you need to find a proper explanation for the result?

Floating and Sinking of an Object in a Liquid: Module Based on Socio-cognitive Constructivism

Theoretical background

The theoretical background that guided the design and development of the present module is aligned with *the socio-cognitive perspective* of learning and *the nature of science*. Some of the important assumptions of this perspective are, for example, the following:

1. Learning results from the interaction occurring between an individual's experiences and his or her current conceptions and ideas.
2. The process of learning depends on the extent to which the individual's conceptions are integrated with new information.
3. Personal construction of knowledge occurs through the interaction between the individual's knowledge schemes and his or her experiences with the environment (both physical and social).
4. The socio-cultural perspective considers the construction of knowledge as a social process, where social transactions and discourse are considered to be the basis for any subsequent learning.
5. Conceptual change is considered a complicated and dynamic process, which is affected by a variety of factors, beyond the cognitive ones, such as, motivation, goals, and perceptions of the task.
6. Inquiry learning within the socio-cognitive perspective incorporates many aspects of the nature of science and its processes.
7. Hands-on activities are valuable only when coupled with minds-on activities or with cognitive engagement.

Brief description of the module

The present module is an attempt to familiarize primary school teachers, lower secondary school teachers, and prospective teachers for primary and lower secondary school with the basic assumptions of *the socio-cognitive perspective* of learning. The module is also an attempt to provide a concrete example of teaching/learning, using *a sinking/floating scenario*. Thus, the module represents an attempt to teach the different concepts regarding sinking/floating, using the described theoretical framework and involving the learners in an inquiry process (active learning/learning by doing). This approach focuses on the learners' initial conceptions and how to promote conceptual change. Within this framework, different ways for identifying learners' alternative conceptions and factors (cognitive and affective) affecting conceptual change are considered very important. Consequently, the learning environment should also encourage rich interactions among the learners and between the teacher and the group of learners.

Competencies to be achieved

The main competencies that should be achieved can be summarized as follows:

- Science teachers must become competent in diagnosing their students' alternative conceptions, using mainly qualitative approaches and formative evaluation approaches.
- Science teachers must be able to design and develop learning environments conducive to conceptual change, taking into consideration their students' conceptions.
- Science teachers must be able to invest on discrepant events that challenge students' existing alternative conceptions.
- Science teachers must be able to identify or design discrepant events that are interesting to and engaging for the students, and are well structured, so that students can be scaffolded to realize the discrepancy between their existing conceptions and the phenomenon.
- Science teachers must be competent to structure problem situations that can provide scaffolding towards possible solutions.
- Science teachers must be equipped with the required abilities for correctly recognizing whether their students experience cognitive conflict or not.
- Science teachers must have the flexibility to differentiate a problem situation according to students' characteristics (e.g., cognitive ability, performance, gender, social and cultural background, etc) in order to enable more students to experience cognitive conflict.
- Science teachers must be able to provide the necessary means for their students to resolve the discrepancies between the phenomena they observe and their existing conceptions.

- Science teachers must be able to provide valuable feedback as to the kinds of reasoning implemented by students, and to help them develop their scientific reasoning skills.
- Science teachers must be competent of identifying non-cognitive factors involved in a cognitive conflict situation and to incorporate these factors productively in the learning process.
- Science teachers must become competent in undertaking their roles as facilitators and supporters, when students attempt to resolve their cognitive conflict situations.
- Science teachers must be able to promote productive social interactions among their students in ways promoting collaboration and shared responsibilities for the knowledge construction process, so that groups of students become real learning communities.
- Science teachers must be able of recognizing their students' conceptual change by identifying students' cognitive gains or conceptual advancement.
- Science teachers must be competent of evaluating their own and their students' conceptions, based on criteria compatible with the tentative nature of science.

Goals of the module

Upon the completion of this module, the pre-service and/or in-service science teachers should be able:

1. to understand and define the basic tenets (principles) of socio-cognitive constructivism.
2. to design and implement teaching scenarios based on socio-cognitive constructivism and following an inquiry-based approach.
3. to appreciate the importance of teaching scenarios that invest not only on cognitive factors, but on affective factors as well, in the process of knowledge construction.
4. to become competent in conducting small scale action research.
5. to continually evaluate students' conceptions and use the evidence for designing more effective teaching/learning situations conducive to conceptual changes.

Content of the module (topics)

The content of the module relates to the different factors affecting the sinking / floating of an object in a liquid. This content can be easily used for primary and lower secondary school students, and it takes into consideration that all, or some of, the students remain concrete thinkers and cannot use abstract concepts. It is thus important to provide observable evidence to the students that challenges their existing conceptions.

Strategies of teaching/ training

The content of the module and the teaching / training strategies or approaches will be clarified by describing an indicative sequence of steps that should be followed during the training. This sequence clearly represents the basic principles of socio-cognitive constructivism and how to implement them, by providing specific examples.

Learners' conceptions should be initially identified and presented to the whole group, so that the participants (teachers or prospective teachers) will be familiarized with the variety of existing conceptions among any group of learners. Learners' conceptions should be somehow made public, so that learners' are familiarized with the spectrum of the existing (pre)conceptions, and, consequently, these should be challenged through specific experimental results, in an attempt to foster cognitive dissonance that will trigger the cognitive processes (assimilation and accommodation) for dissolving this conflict.

Any of the existing alternative conceptions or (mis)conceptions constitutes learners' explanatory frameworks and should be taken into consideration for inducing conceptual change through presenting discrepant events conflicting a learner's conceptions.

For example, data from an interview study with a sample of 5 students from each of three grade levels (fourth, sixth, and eighth grade) indicated that students expressed a variety of different conceptions, when they were asked to provide answers to explain a specific example of floating/sinking. In this study, each student underwent a one-to-one semi-structured clinical interview in a quiet room located away from the classroom setting. Specifically, the interview followed a five-stage process, where the researcher used several combinations of the four identical cylinders in Figure 2. Two of the cylinders contained equal volume of water-like liquids (A and B) and the other two cylinders contained a larger quantity (volume) of water-like liquids (C and D). In each cylinder, there was an egg that was either sinking (B and D) or floating (A and C). Two of the cylinders contained tap water and the other two contained salt solution. The students were not informed at any point about this difference, while there were no observable differences among the liquids in the four cylinders. The four cylinders were hidden from the students, but the researcher had easy access to them and to other materials (i.e., salt, tap water, salt solution etc).

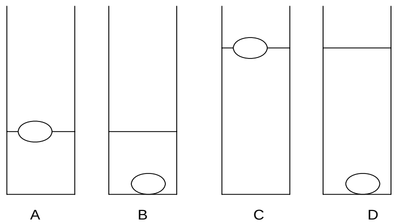

Figure 2. The Four Cylinders that Were Used in the Study

Initially, each student was presented with the combination of cylinders B and C, where the two identical cylinders contained colorless liquid(s) in different quantities. Cylinder B contained less liquid and a sinking egg, while cylinder C contained more liquid and a floating egg, as indicated in Figure 3.

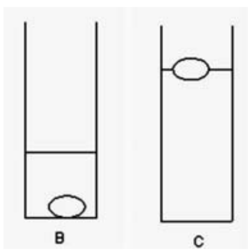

Figure 3. Two Identical Cylinders Containing Different Quantities of Colorless Liquid(S), Where an Egg Is either Floating or Sinking.

After the presentation of the two cylinders, learners were asked to express their existing conceptions, in an attempt to explain and justify the floating/sinking of each egg. For example, they may be asked to state in writing their conceptions relating to the specific scenario, or they may discuss in a whole group their conceptions. In this specific case, students were called upon answering different open-ended questions around the following four issues:

1. *Why do you think the egg is sinking in Cylinder B?*
2. *Why do you think the egg is floating in Cylinder C?*
3. *What do you think will happen, if I switch the eggs in the two cylinders?*
4. *What do you think will happen, if I add some colorless liquid in Cylinder B, so that the quantities of liquid in both cylinders are the same?*

The purpose of this phase was to extract detailed information about students' ideas relating to sinking and floating. Students were not allowed at this stage to conduct any experiments, but they were encouraged and prompted to externalize their understandings about sinking and floating.

The fifteen interviews were then qualitatively analyzed using the constant comparative analysis method. The constant comparative analysis method involves inductive category coding and comparison of observed behaviors across categories (Goetz & LeCompte, 1981). As a consequence of this categorization, patterns are gradually revealed and constantly refined throughout the data collection and analysis process (Dye, Schatz, Rosenberg, & Coleman, 2000). Glaser and Strauss (cited in Lincoln & Guba, 1985) described the constant comparison method as following four distinct stages:

1. comparing incidents applicable to each category,
2. integrating categories and their properties,
3. delimiting the theory, and
4. writing the theory (p. 339).

The results of this qualitative analysis are presented in Table 2. The first column of Table 2 presents the patterns of reasoning that were identified among the 15 students, where, in the second column, the individual students from each class who followed each pattern of reasoning are presented. Column 3 indicates the respective number of students who followed each pattern of reasoning. The three digit identification codes represent students' grade level (4, 6, and 8 for grades four, six, and eight, respectively), their gender (M and F, for male and female students, respectively), while the last digit represents the individual students from each grade level.

Table 2
Students' Initial and Final Conceptions

Sinking and Floating Was Attributed to:	Initial Conceptions	
	Identification Code	n
Only properties of the Object		
1. Mass	**4F1, 6F3**	2
2. Volume	**4M1**	1
3. Change of physical properties due to heating	8F2, 8F3	2
4. Thickness of shell/distribution of weight	**6M1**, **4F2**	2
Total		7
Only properties of the Liquid		
5. Quantity	**4F1,** **4M1**, 4M2, 4M3, 6F1, **6F3,** 8F1, **8F3**, **8M1**	9
6. Temperature	**4F2**, **4M1**, **8M1, 6M1**	4
7. Density/ Kind of liquid	**4M1**, **8M1**, **8F3**, **6M1**	4
Total		17
Properties of Both (the Object and the Liquid)		
8. Quantity of liquid – mass of object	8M2, 6M2	2
9. Density of liquid – Volume of object		0
10. Density of liquid – Density of object	6F2	1
Total		3
Grand Total		27

<u>Note</u>: Bold identification codes in the second column are used to indicate students who did not express consistent ideas.

The results in Table 2 clearly indicate that students' answers could be organized in three qualitatively different categories. In the first category, students expressed the belief that some objects have or acquire the property of floating, and that this property is totally unrelated to the kind of the liquid where these objects are immersed (students 4M1, 4F1, 4F2, 6M1, 6F3, 8F2, and 8F3). As these students clearly stated these objects resemble to boats, ships, or other floating things. Thus, students attributed the floating/sinking phenomenon exclusively to attributes of the specific objects, such as, their mass, volume, distribution of their mass, or their temperature, or they supported the *object hypothesis*, as we termed this group of ideas. For example, a student (8F2) supported that floating/sinking was determined on whether the egg had been boiled and she insisted that a raw egg (un-boiled) would always float, whereas a boiled one would always sink, regardless of the kind of liquid in which it would be immersed. Two other students (**6M1**, and **4F2**[1]**)** insisted that the egg in cylinder C was floating, because its shell was thicker, although they could not observe such a thing. These students seemed to recognize the different parts or materials of an egg, and that the distribution of mass (weight) could affect floating/sinking. The other students who supported *the object hypothesis* did not seem to have clear ideas by referring only to the mass of the object (**4F1, 6F3),** only to the volume (**4M1),** or to the temperature (F2, 8F3) of the object, and did not seem to understand the relation between mass and volume, or how the temperature of an object affects its volume, or that it could not be possible for the object to have different temperature from the surrounding liquid.

Some other students attributed the sinking/floating phenomenon exclusively to several attributes of the liquid, such as, the quantity, the temperature, or the quality of the liquid, or supported *the liquid hypothesis*, as this group of ideas was termed. From this perspective, sea water is a liquid where objects float irrespective of their properties (mass, volume, shape etc.) Specifically, nine students (**4F1, 4M1**, 4M2, 4M3, 6F1, **6F3,** 8F1, **8F3**, and **8M1**) expressed the idea that the more liquid we have, the higher the tendency of the same object to float when put in the liquid. Four students (**4M1**, **6M1, 8M1**, and **8F3)** expressed the idea that whether an object floats/sinks in a liquid depends on the kind of the liquid, while four students supported that whether an object

[1] Bold identification codes indicate students who expressed more than one explanation for sinking/floating phenomenon

floats/sinks depends on the liquid's temperature (**4F2**, **4M1**, **6M1, 8M1),** but they could not justify their reasoning. Interestingly, among these different explanations, only the explanations of four students (4M2, 4M3, 6F1, 8F1, and **8M1**) supported consistently the *liquid hypothesis***,** although student **8M1** was not consistent in his ideas and attributed floating/sinking to the quantity, the temperature, or the density of the liquid. The other students also provided more than one explanation, either within the same category (8M1, and 8F3), or in different categories (4M1, 4F1, 4F2, 6M1, 6F3, and **8F3**) of explanations. The explanations of three other students (4M1, 6M1, and **8F3**) spanned not *only the object* and *the liquid hypotheses*, but also different explanations within *the liquid hypothesis*.

Finally, the other three students (6M2, 6F2, and 8M2) consistently attributed floating/sinking to properties of both the liquid and the object, and their interrelation, while only one of them (6F2) clearly mentioned that the density of the liquid should be higher than the density of the object, but it was not possible to identify whether this sixth-grade female student had a correct conceptualization of the phenomenon, or whether she stated declarative knowledge. We analogously termed this category of ideas as belonging in *the liquid-object hypothesis.*

The overall conclusion from the analysis of students' initial conceptions indicates that the majority of students tended to explain the sinking/floating phenomenon, using either *the object hypothesis or the liquid hypothesis*, while only three students based their explanation on *the object-liquid hypothesis*. More importantly, seven students expressed inconsistent ideas when explaining the floating/sinking phenomenon, while there were no obvious differences between male and female students or among students from different grade levels, except that only fourth- (4M1, 4F1, and 4F2) and sixth-grade (6M1 and 6F3) students provided explanations spanning both *the object* and *the liquid hypotheses*, while eighth-grade students (8M1 and 8F3) provided inconsistent explanations within *the liquid hypothesis* only.

Teaching Interventions

Several teaching strategies for challenging students' expressed conceptions are consequently presented, in an attempt to provide specific examples and clarify the whole approach. These strategies or experiments should be always dependent on the specific alternative conception, as it is exemplified in the following experiments, where different learners' conceptions from the previous study or from the research literature are considered:

Challenging Students' Ideas Aligned with the *Object Hypothesis*

- *Kind (density) of an object.*

In some cases, primary and/or secondary school students suggest that the determining factor for floating/sinking is exclusively the kind of object, that is, floating or sinking is an exclusive property of the objects. Thus, objects have the property to either sink or float, irrespective of the kind (density) of the liquid to which they are immersed in. This idea can be challenged by immersing the same object in two different liquids, so that the object floats in one of them and sinks in the other. For example, a piece of candle can float in water, but it sinks in alcohol.

- *The eggs are different (i.e., one egg is boiled, but not the other).*

For those learners who adopt this explanatory framework, discrepant information can be presented by exchanging the two similar eggs in the two cylinders, or even by alternatively putting the same egg in the two cylinders in Figure 3.

- *Mass (volume or size) of the object.*

Research evidence indicates that a prevalent conception among primary and/or secondary school students relates to the idea that whether an object floats or sinks depends on its mass (volume or size). This conception can be challenged, for example, by immersing a big object in liquid and by immersing next progressively smaller pieces of the same object in the same liquid (i.e., a big piece and very small pieces of wax in water or in alcohol, alternatively). The outcomes of these simple experiments can clearly indicate that the mass of an object alone does not determine whether it will sink or float.

Challenging Students' Ideas Aligned with the *Liquid Hypothesis*

- *Quantity of liquid.*

In most cases, learners think that the quantity of the liquid causes the different outcome in Figure 3. In such a case, the outcome of specific experiments may cause cognitive disequilibrium. For example, by decreasing the quantity of the liquid in cylinder C, so that it will become equal to the quantity of the liquid in cylinder B, in Figure 3. Other examples include the presentation of any information that contradicts the idea that the quantity of a liquid affects the sinking/floating of an object. More specifically, some combinations of two cylinders in Figure 2, such as, A and B, C and D, A and C, or B and D, contradict the specific conception, and constitute discrepant events that may create cognitive conflict and trigger conceptual change.

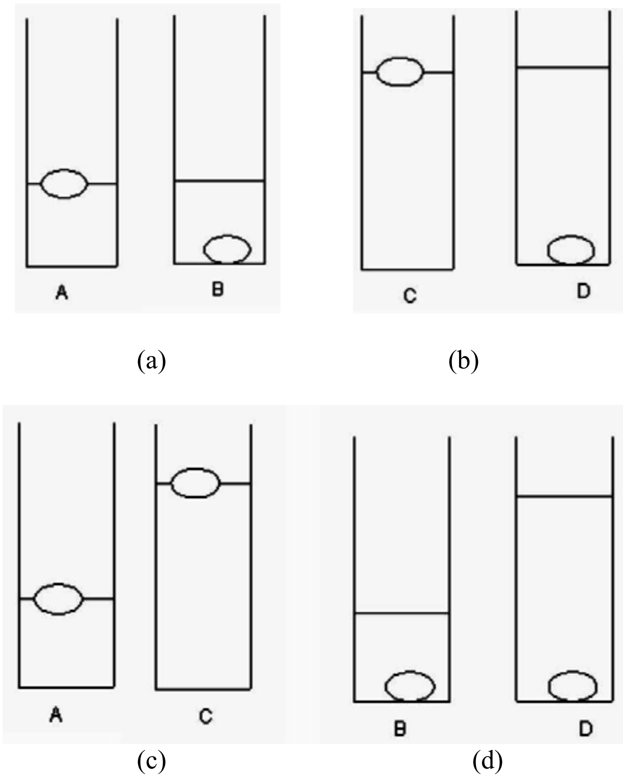

Figure 4. Floating/sinking Is Not Exclusively Dependent on the Amount of Liquid

- *Kind (density) of the liquid.*

In many cases, primary and/or secondary school students insist that the determining factor for floating/sinking is exclusively the kind of liquid, where the kind of solid material is totally irrelevant. Thus, they insist, for example, that any object in cylinder A will float, and any object in cylinder B will sink. This conception expresses an over-generalized conclusion from a limited set of experiences. In such a case, different objects that can either float or sink (i.e., a piece of metal, a piece of wood, apiece of wax, etc.) can be put alternatively in two cylinders containing water or alcohol, respectively.

Refining Students' Ideas Aligned with the *Liquid-object Hypothesis*

i. How can you make the egg in a cylinder, like the one in Figure 5, to be floating?

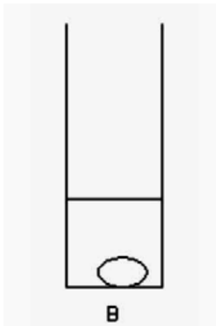

Figure 5. Can you Make the Egg to Be Floating?

Learners should be allowed to propose and test their existing ideas (i.e., adding more water, using a wider cylinder) and should be finally guided to compare the water in the cylinders in Figure 3. They can for example taste it, or measure the mass of equal quantities of liquid from each cylinder, so that they will be sensitized that the liquids in the two cylinders in Figure 3 are somehow different (i.e., tap water and saline water, respectively. They should then be guided to find out (a) how the amount of salt in the same quantity of water affects sinking and floating of the egg, (b) whether the floating/ sinking pattern for other objects (i.e., a piece of wood or a piece of metal) resembles the floating/sinking pattern of the egg, and (c) what kind of differences exist and why.

ii. *Do different objects of the same volume (i.e., identical cubes from different material, such as, wood, candle, plastic, aluminium etc) follow the same pattern of sinking/floating in the same liquid?*

Learners should be guided to compare the mass of the cubes and reach a conclusion explaining the differences. They can also compare the pattern of sinking/floating, when the same cubes are immersed in different liquids.

iii. *How does the mass of an object relate to sinking/floating, provided that the volume remains constant?*

Learners can use floaters of equal volume having progressively increasing mass (i.e., floaters of equal volume from plastic tubes closed from both sides and containing different amount of material, such as sand), so that some sink to the bottom and the others float totally or partially immersed in water. The learners should be guided to reach the conclusion that "*objects having the same volume have higher tendency to float as their mass decreases, while objects of more mass have higher tendency to sink.*"

For example, when the 7 cylinders, presented in the Appendix A (a), are immersed in tap water, then the total pattern of sinking/floating appears as in Figure 6.

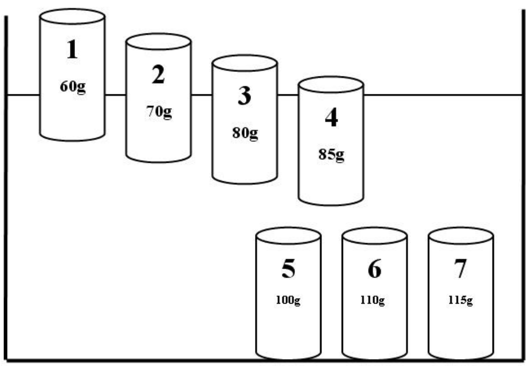

Figure 6. The Seven Cylinders in Appendix A (a), when Immersed in Water

iv. How does the volume of an object relate to sinking/floating, provided that the mass remains constant?

Learners can use floaters of equal mass having progressively increasing mass (i.e., floaters of equal volume from plastic tubes closed from both sides and containing different amount of material, such as sand, so that some sink to the bottom and the others float totally or partially immersed in water. The learners should be guided to reach the conclusion that "*objects having the same mass have higher tendency to float as their volume increases, while objects of smaller volume have higher tendency to sink.*"

For example, when the 7 cylinders, presented in the Appendix A (b), are immersed in tap water, then the total pattern of sinking/floating appears as in Figure 5.

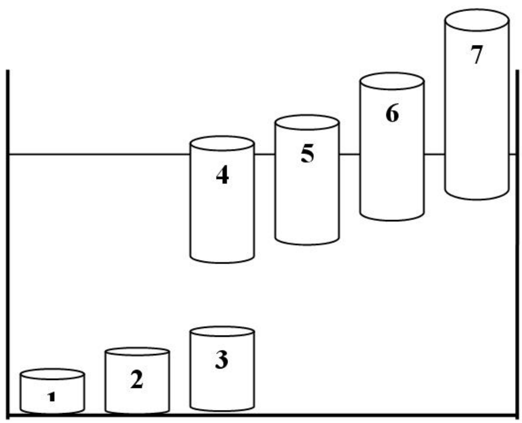

Figure 7. The Seven Cylinders in Appendix A (b), when Immersed in Water

v. Based on the results from iii and iv, learners could be prompted to predict the position of the cylinders in B (c), when these are immersed in water.

What kind of information is needed? Do learners understand the process of prediction and how it is different from guessing? How these processes relate to the nature of science? Learners should be guided to discuss these ideas and compare their predictions with the outcomes of immersing each of the four cylinders in water, as it is shown in Figure 8. These comparisons, depending on students' conceptual progress, may constitute new anomalous situations and trigger another cycle of conceptual change. Conceptual change is not usually a sudden event, or an "all or none" process, but it is rather a continuous and long process.

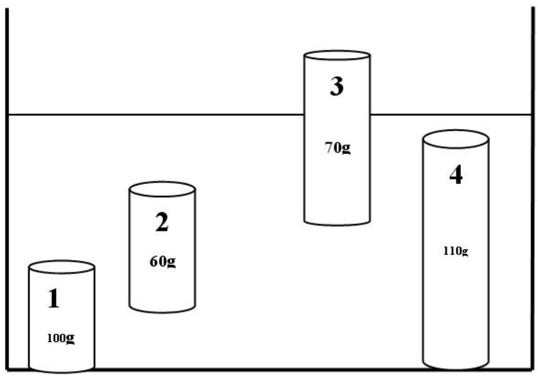

Figure 8. The Pattern of Floating/sinking of the Cylinders in Appendix A (c)

vi. Is it possible to make an object sinking in a liquid to float in the same liquid and how?

For example, learners should be guided to use a piece of candle that sinks in alcohol and make it float by heating it and transforming its shape to resemble a boat. Learners can also wrap a coin in aluminium foil and immerse it in a container of water. They then can make it float by transforming the aluminium foil into a small boat carrying the coin. They can also try to load their "boat" with as many coins as possible and find out by themselves causal relations between different variables.

vii. What is the relation between the volume of an object that is immersed in a liquid and the volume of displaced liquid?

Different experiments should be performed to exemplify that the more an object is immersed, the more is the volume of the displayed liquid.

viii. Is the mass of the displayed liquid equal when the same object is immersed in different liquids?

Different experiments should be performed where the same object (sinking) is immersed in different liquids and measure both the volume and the mass of the displayed liquids.

ix. When an object immersed either in a liquid or a gas (air) sinks or floats partially or totally immersed?

Similar balloons containing either air or helium can be used. The floating helium balloon can be made to sink by externally putting on it different amounts of sticky material, so that it will sink or balance in the air. Students should be guided to understand that on the balloon act two opposite forces, that is, the weight (downward direction) and another force having upward direction (up-thrust), and that their relative magnitude determines whether the balloon will sink, balance in the air, or move upward (buoyancy). Obviously, the relative magnitude of these two opposing forces determines the magnitude of the resultant force. Depending on the relative magnitude of these two forces, there exist three different possibilities, that is:

- The balloon **will balance,** when the magnitude of weight (downwards force) equals the magnitude of up-thrust (upwards force).
- The balloon will move downwards and finally reach the ground (**it will be sinking**), when the magnitude of weight (downwards force) exceeds the magnitude of up-thrust (upwards force).
- The balloon will move upwards, when the magnitude of weight (downwards force) is less than the magnitude of up-thrust (upwards force), and it will finally reach the roof of the room and stop there (**What is the difference between this balloon and the one that balances in the middle of the room or without touching the roof of the room?**)

Similarly, these are the only possibilities when a solid object is immersed in a liquid, and we can make any object to balance, just by changing either the weight of the object or the up-thrust exerted on it, when it is immersed in a liquid. Usually, we change the factors (variables) that affect the up-thrust by changing them accordingly. Understanding of floating/thinking can be correctly conceptualized, when students achieve a deep and correct understanding of Archimedes' principle.

x. When the same object (i.e., an egg or a floater) sinks, balances or floats in salt water? Or how the amount of salt dissolved in water determines whether the same object (i.e., an egg) sinks, balances, or floats?

Learners should be allowed to propose and test their existing ideas by progressively dissolving more and more salt in a container of water (without changing the amount of water) until saturation will occur. (Saturation also relates to the temperature of water. Consequently, how the temperature of a saturated solution affects floating and sinking can be furthermore examined.)

xi. Archimedes' principle (Calculating buoyancy): The volume of displaced liquid.

Learners can also experimentally "test" Archimedes' principle by hanging an appropriate object, for example a metallic cylinder, on a dynamometer and measuring its weight. Then, they should be guided to examine how the reading of the dynamometer changes as they progressively immerse more and more portion of the object into a volumetric cylinder containing a liquid (i.e., water), and compare their experimental evidence. Based on Archimedes' principle, when a body is partially or completely immersed in a liquid, then it experiences an upward force that always equals *the weight of the displaced liquid*, and, consequently, the more liquid is displaced, the higher the up-thrust. Thus, by progressively changing the part of an object that is immersed into the liquid, learners should examine how its weight changes, and correctly conceptualize how the weight of an object hung on a dynamometer changes. They can also observe that the weight of the object, as it is measured by the dynamometer, may reach progressively zero, and a floating object becomes practically "weightless."

xii. Archimedes' principle (Calculating buoyancy): The kind (density) of displaced liquid.

Learners can also experimentally "test" Archimedes' principle by immersing the previous object hung on a dynamometer in different liquids (i.e., water, salt water, alcohol), so that each time the volume of displaced liquid is exactly the same. Thus, they can correctly conceptualize the effect of the kind (density) of a liquid on the reading of the dynamometer. Thus, learners can easily compare their experimental evidence and conclude that the kind (density) of a liquid affects up-thrust, that is, the higher the density, the higher the weight of the displaced liquid. Thus, by progressively comparing the weight of the displaced liquid when the same portion of an object is immersed into different liquids, they can correctly conceptualize how the kind of a liquid (density) affects the force of up-thrust. They can also observe when the weight of the object, as it is measured by the dynamometer, may reach progressively zero, and what the differences in the volume and mass of displaced liquid are, when different liquids are used.

Suggestions

It is however necessary to stress that any kind of experimentation cannot be determined in advance, but it should rather follow the identification of the learners' existing conceptions, as it was described previously. Different learners construct different explanatory ideas depending on their experiences, their age, their cognitive abilities, and other idiosyncratic characteristics. Obviously, learners' conceptions should not be ignored, but these should not only be identified but should be also taken into consideration. These conceptions should be challenged by presenting to the learners conflicting information. This does not mean that teachers should rush to propose specific information or specific experiments, but they should offer to the students the opportunity to discuss and test their ideas, so that they really reach the stage of cognitive disequilibrium.

Nevertheless, even when the learners reach the stage of cognitive disequilibrium, there is no guarantee that the learner will automatically abandon his/her conceptions. These conceptions are usually resistant to change. Consequently, the learners should be also involved in a series of inquiry based activities that should be aligned with socio-constructivistic principles. Some indicative examples where students are scaffolded to answer specific questions have been already presented.

Finally, it should be mentioned that the list of presented ideas is not exhaustive but only indicative. These approaches should be learner-centered where the role of the instructor and the role of the learners change. From this perspective, learners become responsible for their own learning and share autonomy and activities in the teaching/learning situation. Discussions, individual and team work; presentations; involvement of learners in the design, implementation and assessment of teaching interventions; or even synchronous or asynchronous electronic communication are good strategies for a shared construction of knowledge.

A specific example

After the identification of students' initial conceptions about the problem presented in Figure 2, several tactics were used in an attempt to challenge students' expressed ideas relating to the situation of the two cylinders. The different steps of this strategy were aligned to each student's conceptions, as these were expressed during the first stage. For example, when a student had expressed the conception that the larger quantity of the liquid in cylinder C was causing the egg to float, then the researcher could present discrepant information using another combination of cylinders, such as, cylinders A and D, cylinders A and B, or cylinders C and D. The researcher could also pour more tap water in cylinder B, or even pour out some liquid from cylinder C.

Alternatively, when students attribute floating/sinking to any difference between the two eggs (i. e., one being bigger than the other, or one being boiled and the other un-boiled), then the researcher could exchange the two eggs in the two cylinders (B and C), or put the same egg alternatively in both cylinders challenging the child to compare the outcome with his initial ideas/explanations. These and other similar tactics were used to challenge students' alternative (incorrect) ideas explaining the difference between the two cylinders (B and C), and provide evidence contrary to their explanations.

It was thus expected that students would realize the discrepancy of their initial conceptions and the subsequently presented evidence, and would be interested in bridging this discrepancy with the help of the researcher who went on with a 20-minute intervention. During the intervention, the researcher not only discussed with each student his/her ideas and feelings, but they were both involved in experimentation for testing each student's ideas and finding out the factors affecting sinking and floating.

During the intervention (third stage), some of the previous experiments were repeated for clarifying that the amount of water or the egg itself could not provide sound explanations of the sinking/floating situation presented in the initial phase of the process. Each student was also involved in four main activities beyond those presented earlier in the second phase, although the sequence of these activities was not always the same. During these activities:

1. Students were instructed to put alternatively the same piece of solid wax in cylinders containing the same volume of different liquids (i.e., tap water, alcohol, solution of salt in tap water) and compare the results.
2. Students were instructed to cut smaller and bigger pieces of wax, and try whether the floating/sinking result, when these pieces of wax were put in different liquids (i.e., tap water, alcohol, salient solution) or in different quantities of the same liquid, was different.
3. Students were also asked to progressively dissolve more and more salt in a vessel containing tap water and observe the position of the egg, after each attempt.
4. Finally, the students were called upon to observe the position of a solid piece of wax when placed in pure alcohol and, subsequently, to observe the position of the same piece of wax in alcohol, after it were heated and re-shaped into a "boat" by the researcher.

During these activities, students' questions were carefully discussed. At end of the third stage, each participant was presented the four cylinders in Figure 2 and was asked to provide written answers to the following three open-ended questions:

1. *Which of the four cylinders contains tap water (or solution of salt in water)? Please explain why.*
2. *What is going to happen, if I add tap water in each of the four cylinders? Please explain why.*
3. *What is going to happen, if I dissolve the same quantity of salt in each of the four cylinders? Please explain why*

Students' conceptions after the intervention were also identified and students' conceptions in comparison with their initial conceptions are presented in Table 3.

Table 3
Students' Initial and Final Conceptions

Sinking and Floating Was Attributed to:	Initial Conceptions		Final Conceptions	
	Identification Code	n	Identification Code	n
Only properties of the Object				
1. Mass	**4F1, 6F3**	2		0
2. Volume	**4M1**	1		0
3. Change of physical properties due to heating	8F2, 8F3	2		0
4. Thickness of shell/ distribution of weight	**6M1**, **4F2**	2		0
Total		7		0
Only properties of the Liquid				
5. Quantity	**4F1, 4M1**, 4M2, 4M3, 6F1, **6F3,** 8F1, **8F3**, **8M1**	9	***8M2***	1
6. Temperature	**4F2**, **4M1**, **8M1, 6M1**	4		0
7. Density/ Kind of liquid	**4M1**, **8M1**, **8F3**, **6M1**	4	**4F2**, **6F1**, **8M1**, **8F1**, ***6M2***	5
Total		17		6
Properties of Both (the Object and the Liquid)				
8. Quantity of liquid- mass of object	8M2, 6M2	2		0
9. Density of liquid-Volume of object		0	**6M1**	1
10. Density of liquid-Density of object	6F2	1	**4F1, 4M1, 4M2, 4M3, 6F3, 8F2, 8F3,** 6F2	8
Total		3		9
Grand Total		27		15

Note:

1. Bold identification codes in the second column are used to indicate students who did not express consistent ideas.
2. In the fourth column, bold identification codes indicate progression in students' ideas, simple identification codes indicate students who did not change their ideas after the intervention, and identification codes in bold italics indicate regression in students' reasoning

As indicated in the fourth column of Table 3, students' conceptions after the intervention became totally consistent, and were restricted into *the liquid hypothesis* and *the object-liquid hypothesis*. Thus, there were only 4 different categories of explanations, while earlier students provided 9 different categories of explanations. Interestingly, eight students ([2]**4F1, 4M1, 4M2, 4M3, 6F3, 8F2, 8F3,** and 6F2) attributed the floating/ sinking phenomenon to both the density of the liquid and the density of the object, and for floating the former density should be higher than the latter. Only one student (6F2) had initially expressed this idea, while the other seven students expressed initially inconsistent ideas spanning both the object and liquid hypotheses **(4F1, 4M1, 6F3, and 8F3),** or inconsistent ideas within the liquid hypothesis **(4M2, and 4M3),** and student **8F2** attributed the sinking/floating phenomenon to the temperature of the object. One additional student **(6M1)** attributed the phenomenon to the density of liquid and the volume of object, while the same student provided initially inconsistent ideas spanning both the object and the liquid hypotheses.

Five other students (**4F2, 6F1, 8M1, 8F1**, ***6M2)*** did not develop totally correct understanding of the phenomenon, and attributed the floating/sinking to only the density of the liquid without mentioning the object and its characteristics (mass, volume, density etc). Four of these students initially explained the phenomenon by referring to the liquid hypothesis (**6F1, 8M1**, and **8F1**), or to both the object and the liquid hypotheses (**4F2**). The other student (**6M2**) who initially attributed the phenomenon to a relation between the quantity of liquid and the mass of the object, attributed, after the intervention, sinking/floating to the density of the liquid., Student 8M2 was the only one who, despite the intervention, regressed towards the totally incorrect conception that the floating/sinking depends only on the quantity of liquid where the object is immersed, although he initially attributed sinking/floating to a totally correct conception.

Representative excerpts from the individual interviews with students are thus discussed in an attempt to shed more light on their understandings and their way of thinking. The first excerpt relates to the interview with participant 6M1, where "I" always indicates the interviewer.

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[2] Bold identification codes indicate, from now on, students who progressed in their understandings of the floating/sinking phenomenon.

I. *Why do you think the egg is sinking in cylinder B?*

6M1 *Because the density of the liquid is less and it leaves the egg to fall down.*

I. *You mean less than what?*

6M1 *Because water is less dense and it does not look as dense as oil.*

I. *Why does the egg float in Cylinder C?*

6M1 *It's like when we go to the beach and there is salt inside the sea, and it does not let us sink. This is because of the density of the liquid. The salt has this property to make the water denser and therefore it does not leave the egg to fall to the bottom. […] In the salty water, when you put a big marble, then it would not be able to keep it to the surface. You will need to add more salt. Also, when you see a boat in the sea, only the "basis" of the boat is touching the water.*

I. *When you say the "basis," what do you mean? Does it have anything to do with whether the boat floats or sinks?*

6M1 *The part which comes in contact with water could be as small as the bottom of a pin. The pressure which occurs when an object, like a ship, is touching another object is very small, because the outer surface of a ship is very big.*

It seems that the student (**6M1**) supported that floating/sinking depends upon the relationship between the density of the liquid and the volume of the object, or the shape of its outer surface. Although the student did not manage to reach the scientifically accepted explanation, he managed to abandon his initial pattern of reasoning according to which he supported *the object* and *the liquid hypotheses*, alternatively, and to construct a more sophisticated explanation for the phenomenon. This explanation falls within the *object-liquid hypothesis***.** Student **6M1**'s conception of the density of the liquid and its role in buoyancy was not however the scientifically accepted one. Thus, he stated that the higher the density of the fluid, the more likely it is for an object to float, but he could not understand buoyancy as the result of two opposing forces, (one upwards and one downwards) and, instead, he focused on the concept of fluidity of the liquid. The student stated explicitly and incorrectly that oil had "*higher density*" than water, and that, by adding more and more salt in water, its density increases rather indefinitely and without reaching probably saturation. The student went on to describe how "the shape of the outer surface of a boat" affects floating/sinking. This latter explanation seemed to be an incorrect transfer of totally declarative knowledge from the study of the concept of pressure in solids.

Student **6F3** initially supported quite contradictory ideas explaining that the position of an object, when it is immersed in a quantity of liquid, can be determined exclusively by its mass or by the quantity of the liquid, or the kind of liquid. Through the intervention, she gradually managed to progress towards the scientifically accepted explanation of the phenomenon. As a first step, she considered that floating/sinking was determined exclusively by the thickness of the outer shell of the "boat" of wax, and, subsequently, she was able to relate the concepts of mass and volume of the object, and achieve an understanding of the concept of density. She progressively managed to understand that the higher the density of the liquid, the most likely it is for the object to float, and, thus, to provide a totally explanation of floating/sinking. She also realized that it is more likely for a "boat-shaped" object to float compared to a solid object of the same mass, and that in order for a "boat-shaped" object to float, it must have a certain mass compared to the volume of the object (not the volume of the material of the object). The following excerpt from the interview with student **6F3** indicates her gradual progress towards conceptual understanding.

I. *[…] How can I change this piece of foil in order to make my object float? (The object is a coin, tightly wrapped in a piece of foil).*

6F3 *Maybe, I can make it look like a boat.*

I. *Good, now make it look like a boat […]. Be careful, so that water can't get inside your boat…. There you are!*

6F3 *Here we are. We have our boat. We made it float.*

I. *Why don't you try to put coins inside? [She tries]*

6F3 *Yes. Two, three, four, five, six, seven, eight… That is because of the shape of the boat. Eight!*

I. *It still hasn't sunk. There we are (she added one more coin)…it is sinking now! …. So, does our boat always float, regardless of its mass?*

6F3 *It comes to a point where it can't lift any more coins.*

I. *Good. […] Was this mass high?*

6F3 *Yes, we put too many coins on the boat, considering that before changing the shape of the foil, the object would sink with only one coin. We changed the kind of the object.*

The following is one additional excerpt from the interview with student 8F3, where she explained why she attributed sinking/floating to the temperature of an object.

I. *[…] What could be the factor, which determines the positions of the two eggs in Cylinders B and C?*
8F3 *The temperature of the object!! (*This is totally incorrect*.) Why?*
I. *Do you mean that one of them is hot and the other one is cold?*
8F3 *Yes.*
I. *Which one do you think is hot?*
8F3 *The one in Cylinder C*
I. *And which one do you think it is cold?*
8F3 *The other one. The one in Cylinder B.*
I. *Why do you think that?*
8F3 *Because C is in the water, but it is higher, towards the surface compared to B, so it gets more heat.*
I. *From where?*
8F3 *From the room.*
I. *So, you think that heat makes an object to….*
8F3 *Float.*

Student **8F3** expressed the common alternative conception that heat has material existence being a kind of liquid substance, which is "transferred" to the object by the surrounding environment. For her, heat has the property of facilitating an object to float, despite the fact that, due to its material existence, "it increases its mass." The student also expressed inadequate ability for reversible thinking, since she supported that even when the wax - after being heated and reshaped- became again solid after cooling it, its mass would be less compared to its initial one.

I. *Do you think that if this piece of wax was shaped like a boat, would this have an effect on its position?*
8F3 *Is there a way to try?*
I *Yes. How could I turn this piece of wax into a boat?*
8F3 *Maybe, if I heat it and put it in some kind of mould?*
I. *Yes, I can heat it up and reshape it with my hands.*
(The student performs the experiment)
I. *OK, now put it in the alcohol.*
8F3 *(after putting the "wax boat" into alcohol). It does not sink.*

I. *So, now we discover another factor which affects floating and sinking.*
8F3 *The kind of material?*
I. *But, it is always wax. What do you mean?*
8F3 *When we melt it, it became lighter.*

According to *the liquid hypothesis* presented in Table 1, floating/sinking is exclusively determined by properties of the liquid, while the properties of the object are irrelevant to its position when it is immersed in a fluid. Students **4F2**, **4M1**, **8M1** and **6M1** supported that the temperature of the liquid is the factor which determines the position of the egg. Students **4M1**, **6M1** and **8M1** supported that the higher the temperature of the liquid, the most likely it is for the object to float.

Only three participants (**6F1, 8M1,** and **8F1**) expressed prior and after the interview ideas consistent with *the liquid hypothesis***,** but, after the intervention, they attributed floating/sinking exclusively to the density of the liquid. This idea was the most sophisticated explanation within the set of ideas relating to *the liquid hypothesis* and was considered as a progression towards the scientifically accepted explanation. This progression is demonstrated in the following two excerpts from the interview with participant **8F1**.

I. *Why do you think the egg is sinking in Cylinder B?*
8F1 *Because it contains less water.*
I. *Why does it float in Cylinder C?*
8F1 *Because it has more water.*
I. *What do you think would happen, if I exchanged the eggs in Cylinders B and C?*
8F1 *In cylinder B, it would sink and, in cylinder A, it would float.*
I. *So they would take exactly the same positions?*
8F1 *Yes.*
I. *OK. And what do you think would happen if I added water in Cylinder B, so that the level of the liquid in Cylinders B and C would become the same? Where would the egg go?*
8F1 *To the surface*

Thus, the student (*8F1*) initially expressed the idea that the larger the quantity of the liquid, the easier it is for an object to float. After the intervention, the same student (**8F1**) shifted to a different conception within the *liquid* *hypothesis.* More specifically, he attributed floating/sinking to only the (kind) density of the liquid. Finally, the student (8F1) managed to correctly recognize that two of the four cylinders in Figure 2 contained tap water and the other two saline water, but she continued to face difficulties in correctly conceptualizing the concept of density, as it is clarified by the following excerpt.

I. *What would happen if I added water in Cylinder B?*
8F1 *Our egg would go somewhere in the middle of the cylinder.*
I. *What makes you believe that?*
8F1 *Because when water mixes with salty water, then the egg would stay there. Because salty water contains salt and water. If we add any of these two substances, then there won't be a reaction*
[…]
I. *What interests you the most?*
8F1 *In liquids which have the same weight, can the same object reach to a different level or height, depending on the liquid?*

Obviously, the student (**8F1**) could not understand that the density of saline water can take different values depending on the amount of salt relative to the amount of water, and attributed floating to the weight of the liquid rather than to its density. These ideas clearly indicate the existing gaps in her understanding, even after the intervention.

Only one sixth-grade female student (6F2) expressed correct understanding of floating/sinking both prior and after the intervention. The student demonstrated stability of conceptions- student 6F2- and consistently stated the *scientifically accepted* explanation of the phenomenon before and after the intervention. Therefore, participant 6F2 had probably reached a ceiling effect (Liu & Lederman, 2002). The stability to the scientifically accepted explanation before and after the intervention is evident in the following abstract from the interview with student 6F2.

(The participant observed the position of a solid piece of wax in alcohol and then heated, and reshaped the piece of wax into a boat and placed it again in alcohol).
I. *What did we change in this piece of wax in order to make it float?*
6F2 *Its shape. The boat has more … surface.*
I. *What do you mean?*

6F2 *That the wax, when it is solid, it is not as wide as it is when it looks like a boat.*
I. *Could you explain that?*
6F2 *The same thing happens to the boat, because it is not shaped like a cube. It has empty space inside. It is not solid.*

Two other students (8M2 and 6M2) regressed, after the intervention, from *the object-liquid hypothesis* to *the liquid hypothesis*. Both of them attributed floating/sinking to the relationship between the quantity of the liquid and the mass of the object. After the intervention, one of them (6M2) attributed sinking/floating to the density of the liquid, and the other (8M2) regressed to a more naïve conception and attributed floating/sinking to only the quantity of the liquid, as it is shown in the following excerpt from his interview.

I. *What would happen if I exchanged the two eggs in the cylinders […]? (*The excerpt refers to the combination of Cylinders B and C presented in Figure 2*)*
8M2 *Would they both sink?*
Why?
8M2 *Because this one is small and light.*
I. *What do you think would happen if I put water in Cylinder B, so that the level of liquid in Cylinder B would become equal to the level of the liquid in Cylinder C?*
8M2 *I think the egg would rise up to here.*
I. *You mean that the egg would rise to the middle of the cylinder? Why?*
8M2 *Because, there would be more water in the cylinder.*

During the diagnosis of his final conceptions, the same student (8M2) attributed floating/sinking exclusively to the quantity the liquid, which indicates that the approach implemented during the intervention was not productive for him. The following excerpt from the interview with student 8M2 exemplifies his thinking.

I. *What do you think will happen, if we pour more liquid in Cylinder A? Where will the egg go?*
8M2 *Up*
I. *Why?*

8M2 *Because, if I pour some water outside of the cylinder, to reduce its quantity, then the egg would still be at the bottom of the new quantity of water. If I add more water, it will lift up the egg.*

In the previous excerpt, student 8M2 attempted to explain the phenomenon of floating/sinking by referring merely to the quantity of the liquid, since he perceived that the larger the quantity of the liquid, the most likely it is for an object to float. In addition, in the following excerpt, which comes from the interview with participant 6M2, prior to his involvement in the intervention, it is evident that he implemented *the object-liquid hypothesis* to explain floating/sinking. More specifically, he referred to the relation between the quantity of the liquid and the mass of the object, as was also the case with participant 8M2.

I. *Why do you believe the egg is sinking in Cylinder B and why the egg in Cylinder C is floating?*
6M2 *The water is not of the same quantity.*
I. *What do you mean? Could you explain this further?*
6M2 *Cylinder C contains more water, and maybe the egg in Cylinder B is heavier. If the egg was lighter in Cylinder B, maybe it would float, considering of course that there would be enough water in the cylinder to lift it up*

However, the same student (6M2) regressed, during the diagnosis of his final conceptions, to the *liquid hypothesis* and only referred to a naïve conception of the concept of the density of the liquid as the exclusive factor determining floating/sinking. More specifically, participant 6M2 seemed to consider that density is a property of the liquid, which remains stable even if water was added to the saline solution. Therefore, in his explanation of the phenomenon of floating/sinking, he did not take under consideration any modifications of the density of the liquid. Having adopted the liquid hypothesis as an explanatory framework for floating/sinking, the student did not seem to have an adequate understanding of the concept of density, as demonstrated in the following excerpt.

I. *What do you think would happen if I added some water in Cylinder B, so that the amount of liquids in Cylinders B and C would become the same?*

6M2 *I think that the egg in Cylinder B would still sink, because the quantity of water has nothing to do with whether the egg sinks or floats.*

[…]

I. *What do you think would happen, if I added some water in Cylinder C? Where would the egg go?*

6M2 *The egg would still float, because we would have still a solution of salt in water and eggs float in salty water.*

In the previous excerpt, participant 6M2 seemed to consider that density is a property of the liquid (saline water), which remains stable even if more water is added. Therefore, in his explanation of the phenomenon of floating/sinking, he did not take under consideration any modifications of the density of the liquid. Having adopted *the liquid hypothesis* as an explanatory framework for floating/sinking, the student did not seem to have an adequate understanding of the concept of density.

Components of CC

Finally, students were asked to describe their CC experience, using the items of the CCLT (Lee et al., 2003) as a protocol, that is, students were required to describe the way they had experienced the cognitive and affective components of CC.

Analysis of the diagnosed components of CC

The CCLT (Lee et al., 2003) was used as a protocol in order to diagnose how the students experienced the cognitive (*recognition of anomalous* data and *cognitive reappraisal* of conflict situation) and the affective (*interest* and *anxiety*) components of CC. For the purpose of the present research study, the twelve items of the CCLT (Lee et al., 2003) were transformed to open-ended questions, so that students could detail their experiences. Subsequently, the interview transcripts were analyzed using the Constant Comparative Analysis Method (Lincoln & Guba, 1985; Dye et al., 2000) and the patterns of answers for each of the components of CC were identified. It was thus concluded that for each of the components of CC, the different patterns of students' answers could be organized in three distinct categories. The results of the interview analysis concerning the components of CC are presented in Table 4.

Table 4
Diagnosis of Cognitive and Affective Components of CC

Participants	Recognition			Interest			Anxiety			Reappraisal		
	Complete	Partial	None	High	Medium	Low	High	Medium	Low	Complete	Partial	None
4M1		x		x					x		x	
4M2		x		x					x		x	
4M3		x		x				x			x	
4F1		x		x			x			x		
4F2	x			x					x		x	
6M1	x			x				x			x	
6M2	x				x			x		x		
6F1	x			x					x		x	
6F2	x				x			x			x	
6F3		x		x				x			x	
8M1	x					x			x		x	
8M2	x				x			x		x		
8F1		x		x				x			x	
8F2	x				x				x	x		
8F3	x			x			x			x		
Total	9	6	0	10	4	1	2	7	6	5	10	0

Recognition of the anomalous situation was diagnosed using the first three questions of the CCLT (Lee, et al., 2003), which is presented in Table 1. When a participant mentioned that he/she was able to recognize the anomalous situation and could verbally explain the content of the anomalous data, then he/she was grouped under the category ***"**complete recognition of the anomalous data.**"*** When a participant could recognize the anomaly, but could not accurately define the content of the anomalous situation, then he/she was categorized as having reached a ***"**partial recognition of the anomalous data**."*** Finally, participants who stated that they did not recognize any discrepancy between their initial and final conceptions were put under the ***"**none**"*** category.

In an almost similar way, three levels of interest that were labeled as "*high*," "*medium*," and "low" were used to categorize students responses' to the next three questions of the CCLT. A participant was categorized as expressing a ***"**high level of interest**,"*** whenever he/she could not only express verbally that the process was very interesting to him/her, but also to justify the reasons or the content that triggered his/her interest. The category ***"**medium level of interest**"*** included the participants who verbally expressed that the process was interesting to them, but they were not able to describe the part of the procedure which they found interesting. Finally, the participants who stated that the process was not interesting to them were categorized as having demonstrated *"low level of interest."*

Students' responses to Questions 7-9 of the CCLT were used to identify their level of anxiety. Thus, the participants who stated that they experienced anxiety throughout the interview were categorized as having *"high level of anxiety."* Those who mentioned that they had experienced anxiety at the beginning of the procedure, but they gradually overcame their anxiety through their involvement in the inquiry process were considered as having *"medium level of anxiety,"* while those who mentioned that they had not experienced any anxiety were considered as having *"low level of anxiety."*

Finally, based on students' responses to the last three questions of CCLT (Questions 10, 11, and 12), three distinct categories of cognitive reappraisal were also considered. Thus, those participants who not only recognized that their final conceptions differed from their initial ones, but they also specified the content of those changes, were categorized as having *"completely"* reappraised their conceptions. Accordingly, those participants who stated that their initial and final conceptions were different, but they could not spelled out the content of these changes, were categorized as having *"partially"* reappraised their initial conceptions. Finally, those participants who stated that their initial conceptions remained unchanged were categorized as not having reappraised their initial conceptions (*"none"*).

Recognition of anomalous data

As presented in Table 4, all participants recognized the anomalous situation, but not always with the same accuracy or at the same level. Nine participants (4F2, 6M1, 6M2, 6F1, 6F2, 8M1, 8M2, 8F2, 8F3) were able to report the exact moment, during the procedure, at which they realized that their conceptions were inadequate to provide a satisfactory explanatory framework for the presented problem. Nevertheless, only three (6M1, 8F2, 8F3) out of these nine students were able to progress towards more scientifically accepted explanations. Evidently, recognizing the anomalous situation does not guarantee the alleviation of CC, since the discrepancy was identified even by the two students- 8M2 and 6M2- who had regressed from *the object-liquid hypothesis* to the *liquid hypothesis* after the intervention. The following excerpts provide more information for students' ability to recognize the anomalous situation.

I. *When you saw the four cylinders (Figure 2) and tried to explain why the eggs were in those positions at the beginning, did you have any doubts about your answers?*

6M1 *Yes, because at the beginning I believed that something else was going to happen. Some of those positions did not make any sense to me.*

I. *Could you describe what was it that you needed to learn in order to explain why the eggs had taken those positions?*

6M1 *The fact that the weight of the object is necessary to understand floating, and that I need to learn the proportions required.*

I. *What do you mean "proportions?"*

6M1 *Between salt and water, or between the weight and the shape of the object, the volume…*

I. *Good. […] When we did the experiments, did you have any doubts concerning the reasons that caused those results?*

6M1 When we started, I had some doubts, but after we did the experiments, my doubts were not there any more.

In the previous excerpt, student 6M1 pointed out that he recognized the discrepancy between his initial conceptions and his observations. Then, he focused his attention on the concept of the density of the liquid and on the mass of the object, and he realized the need to relate these two factors in order to explain floating and sinking. Although this is not the scientifically accepted explanation for the phenomenon, it is yet close to it and more sophisticated compared to the participant's initial explanation. Therefore, participant 6M1 managed to progress towards the scientifically accepted explanation.

From the next excerpt, it is evident that student 6F2 correctly realized the discrepancy between her initial and final conceptions. More specifically, she realized that she initially omitted to relate properties of the egg with properties of the liquid. According to the student (6F2), her involvement in the inquiry process facilitated her to gradually alleviate the discrepancy, despite the fact that she was not able to implement her reappraised conceptions, and she rather remained stable to her initial ideas.

I. *When you saw these two different results, were the reasons that caused them clear, or did you have any doubts as to why they were happening?*

6F2 *No, they were clear to me after some time and I understood better how they affected floating, or what the relationship is between salt, water, and the egg.*

I. *At that exact moment, when something different than what you expected happened, how did you feel?*

6F2 *I felt excited that I saw it happening.*

As demonstrated in Table 4, six of the participants (4M1, 4M2, 4M3, 4F1, 6F3, 8F1) were categorized as having partially recognized the anomalous data. These participants were able to realize that their initial conceptions could not provide an adequate explanatory framework, towards the solution of the problem presented in Figure 2. However, they could not identify what the content of the discrepancy was, which means that they could not indicate the aspects of their conceptions, which were in conflict with their observations. Interestingly, five out of these six participants (4M1, 4M2, 4M3, 4F1, and 6F3) were able to progress towards more sophisticated explanations of the floating/sinking phenomenon after the intervention. Therefore, these participants were categorized as having partially recognized the anomalous situation, as indicated in the following excerpt:

I. *When you realized that what you expected to happen was in some cases, a little bit different than what you observed happening, how did you proceed?*

4F1 *At the beginning, I thought that we would do 1-2 experiments. Then, as we did more experiments, I clearly understood what was happening.*

Through the previous excerpt, it is evident that participant 4F1 realized that there was a discrepancy between her conceptions and the scientifically accepted explanation of the phenomenon of floating/sinking. However, she was not able to indicate at which part of the procedure she had realized this anomaly or to accurately identify the content of the discrepancy. Instead, she limited her explanation of the discrepancy to mentioning that the process of solving the problem presented in Figure 2 was more complicated than what she had expected, and that the process required a series of experiments.

Interest

The participants were also asked to describe whether the procedure was interesting for them, after they realized the discrepancy between their existing and the scientifically accepted conceptions. The participants were required to identify the elements of the procedure which they found most interesting, and to point out any possible further investigations they would be interested in conducting, after the reappraisal of their initial conceptions. The answers provided were not limited to the description of students' interest due to the recognition of the anomalous data, but also to their general interest regarding the process of resolving the CC and the content of the interventions.

As shown in Table 4, ten out of the fifteen participants (4M1, 4M2, 4M3, 4F1, 4F2, 6M1, 6F1, 6F3, 8F1, 8F3) expressed a high level of interest during their engagement in the problem-solving process. These students were highly enthusiastic and clearly demonstrated their interest during their interviews. According to the participants, their interest was inspired by the fact that they were actively involved in the procedure, after the recognition of anomalous data, aiming towards resolving the CC. Some of the subjects who demonstrated a high level of interest specified their interest to the resolution of the CC and its impact on their conceptual change. Others focused their interest on the explanation of the experimental results and towards examining the generalizability of their new conceptions, by investigating the position of the eggs, or other objects, when these are placed in different liquids.

Eight out of the ten participants, who expressed a high level of interest (4M1, 4M2, 4M3, 4F1, 4F2, 6M1, 6F3, 8F3), had also progressed towards the scientifically accepted explanation of the phenomenon, whereas the remaining two (6F1, 8F1), out of those ten, did not change their initial pattern of reasoning even after the intervention. This indicates that positive emotions, such as interest, could provide motivation towards the solution of CC and therefore promote conceptual change.

The following excerpts from the interviews with participants 4F1 and 6M1 are representative of their high level of interest:

I. *How interesting was this whole process for you?*
4F1 *Very interesting, because I learned something new that I didn't know before. The more salt you put in water, the easier it is for the object to float.*
I. *Good […]. Are you curious to find out more about floating/sinking?*
4F1 *Yes.*
I. *What are you interested in learning?*
4F1 *I would like to try, let's say, with other liquids, like if you add salt in alcohol, whether the egg….will float, or if you use soft drink, as I mentioned before.*
I. *Did the experiments draw your attention?*
4F1 *Yes.*

As presented in the previous excerpt, participant 4F1's interest emerged as a result of her engagement in the process of alleviating CC and, more particularly, from the fact that she was able to construct an adequate explanatory framework of floating/sinking. Moreover, her interest was focused on extending the investigation and, more particularly, to examine the position of the egg in solutions of salt and various kinds of liquid, such as, alcohol or soft drinks. On the other hand, student 6M1 expressed a high level of interest from the beginning of the interview, which was maximized after his engagement in the procedure. Student 6M1's interest is evident in the following excerpt:

6M1 The experiments were interesting, because I like my science class and I like to calculate things, to perform or observe experiments, and to examine their applications in real life.

I. From the moment you observed the results of your experiments were you curious to learn more about floating/sinking or was your curiosity satisfied with the experiments we did?

6M1 No, I was not satisfied, because I keep wondering how each of the things around me is created, how it works, and I think by myself based on what I observe, how each thing was constructed.

I. So do you mean that you compare what you learn at school with your everyday experiences?

6M1 Not only at school. And from TV, from some documentary, for example, from the news… A few days ago, I was curious about how people make energy […]. I understood this, because we did a lesson in our science class.

I. Good. What was your lesson about?

6M1 When we learned about the pressure that comes from an object with a narrow surface. I forget the word. It was in the chapter of pressure. For example, we put a box of matches in a bowl of flour- its smaller surface- and the trace was deeper compared to the trace of its bigger surface. When we put weight on top of the box, the trace was deeper.

Student 6M1 expressed a high level of interest to solve the problem, which derived from his general interest for science. The student (6M1) seemed to have a natural curiosity towards explaining phenomena that he encountered during his everyday experiences. His statement "*I think by myself*" indicates that his cognitive processing, or his thought experiments, extends well beyond the formal school setting. Also, there was a transfer of knowledge from another framework (pressure in solids) and the incorrect consequent explanation of the factors affecting floating/sinking. However, when the student realized that his existing conceptions did not provide an adequate explanatory framework concerning floating/sinking, and, therefore, recognized the anomalous situation, he demonstrated a high level of interest towards understanding the phenomenon.

As presented in Table 4, subjects 6F2 and 8F2 demonstrated a medium level of interest, which means that they verbally expressed that the procedure was interesting to them, without being able to identify the content of their interest or in which part of the procedure they were most interested. The following excerpt from the interview with participant 6F2 is a good example of a medium level of interest, which might have contributed towards the stability of students' reasoning before and after the intervention.

I. *How interesting was this procedure for you?*
6F2 *Regular. Not too much and not too little.*
I. *After you made some observations during our experiments, were you curious to learn more about this issue?*
6F2 *Yes.*
I. *What would you like to learn for example?*
6F2 *To learn whether the eggs would sink or float, if we put some other liquids in the cylinders.*

As presented in the previous excerpt, despite the fact that student 6F2 was not enthusiastic, yet she demonstrated interest to expand her inquiry regarding the positions of various objects in various kinds of liquids. This simply indicates that the student kept her curiosity or interest during the process of alleviating the CC.

The following excerpt comes from the interview with student 8M1, who demonstrated a low level of interest and did not change his initial pattern of reasoning after the intervention:

I. *Were these experiments interesting for you?*
8M1 *Not so much.*
I. *Why?*
8M1 *Because, I knew that sometimes you put some other materials in the water and the objects float, whereas if you had water only the objects would either always float or they would always sink.*
I. *Are you curious to investigate floating/sinking and the factors affecting it a little more?*
8M1 *No*
I. *Why?*
8M1 *Because, it's too easy for me.*
I. *[…] but did the procedure we did, with all the experiments, draw you attention?*
8M1 *Yes, kind of…*

Student 8M1 demonstrated a low level of interest for the problem. From the beginning of the interview he considered that, by using his initial conceptions, he could provide an adequate explanation as to the factors affecting floating/sinking. Therefore, he did not consider the problem to be challenging. However, a more careful examination of the excerpt reveals that student 8M1's interest could easily be aroused if more attention was focused on his specific interests, since students' interests in everyday teaching interventions is highly influential on science learning outcomes.

Anxiety

The recognition of the inadequacy of students' current conceptions to explain the factors affecting floating/sinking is possible to arouse negative emotions, such as anxiety, which is considered to be one of the affective components of CC (Lee et al., 2003). As presented in Table 4, for seven of the participants (4F1, 6M1, 6M2, 6F2, 6F3, 8F1, and 8M2) anxiety was experienced temporarily after the recognition of the anomalous situation. This anxiety was gradually overcome, during participants' active involvement in the intervention and was labeled as *"medium level of anxiety."* For three of the students (4F1, 4F2, 8F3) anxiety was high throughout the entire interview and was grouped under the category *"high level of anxiety,"* whereas for five participants (4M1, 4M2, 6F1, 8M1, 8F2) anxiety was not experienced or was kept at low levels and were grouped as having *"low level of anxiety."* These participants were motivated to solve the problem by curiosity and enthusiasm, and, therefore, they did not experience anxiety or uneasiness, during their efforts to solve the problem.

For example, participant 4M2 also managed to progress towards the scientifically accepted explanation of floating/sinking after the intervention. Despite the fact that this participant had recognized the discrepancy between his conceptions and an adequate explanation of the factors affecting floating/sinking, yet he was not disturbed or discouraged and demonstrated low level of anxiety. Instead, as presented in the following excerpt, participant 4M2 demonstrated curiosity, which seemed to derive from his personal interest for the phenomenon and from the context of the intervention, which he seemed to find original:

I. *At that moment, when you observed that something different than what you expected was happening, what did you feel, what was your reaction?*
4M2 *That there are some things that are not as we think they are. They are different.*
I. *Did that make you feel puzzled?*
4M2 *No.*
I. *What were your emotions? Positive or negative?*
4M2 *They were good! I liked the idea…*

The following excerpt from the interview with participant 6F1 indicates the low level of anxiety student 6F1 experienced:

I. *Did you feel anxiety when you realized that some of the things that you observed were different from the ones you expected to happen? Did you experience any negative emotions?*
6F1 *No, I felt that I could learn something new.*
I. *The moment you came across the new problem, the one with the four cylinders, how did you feel?*
6F1 *I felt that I could easily answer to your questions, if I remembered the experiments we did before.*
I. *Was there anything, during the procedure, which did not convince you or confuse you?*
6F1 *No, everything was clear.*

As demonstrated in the previous excerpt, student 6F1 experienced positive emotions from the beginning of the interview, despite the fact that she eventually had to reappraise her initial conceptions. Therefore, she felt confident to apply the knowledge she acquired during the intervention and attempt to solve any problem concerning floating/sinking. Additionally, it appears that the intervention was convincing for the student, since she considered that there were not any further or unexamined factors affecting floating/sinking, beyond the ones examined during the intervention. However, during the diagnosis of her final conceptions, this participant did not change her initial conceptions, since she could not adequately apply the new knowledge for solving the problem that was subsequently presented to her.

Participants 4M3, 6M1, 6M2, 6F2, 6F3, 8M2, and 8F1 stated, during their interviews, that each time they encountered an experimental situation, they initially felt anxiety, which was gradually overcome through their engagement in the procedure. Therefore, these seven participants were categorized as having expressed a "*medium level of anxiety*". Three out of these seven students (4M1, 4M3, and 6F3) managed to progress towards the scientifically accepted explanation of the phenomenon after their engagement in the intervention, two (6F2, 8F1) did not change their initial pattern of reasoning, whereas the remaining two students- 6M2 and 8M2- regressed to more simplified or "naïve" explanations.

The following excerpt relates to an interview with participant 6M1, who had also progressed from the alternative use of *the object hypothesis* and *the liquid hypothesis* to *the object liquid hypothesis* and provides a good example of medium level of anxiety.

I.	*So, did you have any doubts when you expressed your first ideas?*
6M1	*Yes, and I did some predictions*
I.	*How did you feel when you realized that what you observed in the experiment were different than what you believed would happen?*
6M1	*I understood that I had made a mistake at the beginning and now I know what the right thing is.*
I.	*Some of your initial ideas were right and some were wrong. When you realized that what would happen was different than what you expected, did you feel bad?*
6M1	*I felt a little uncomfortable. This happens to me very often, to say something that is not right, but I was curious to learn what would happen next.*

It is possible that participant 6M1 initially experienced anxiety, when he came across the experimental situation presented in Figure 2. However, through the interview it appeared that, during his active engagement in the inquiry process that followed the presentation of the problem, he was able to overcome his negative feelings.

Participants 4F1 and 8F3 experienced high levels of anxiety throughout the interview. These participants also demonstrated low self-confidence and expressed their conceptions reluctantly. The following is a characteristic excerpt from the interview with participant 8F3:

I. *At some moment you realized that what you expected to happen was different compared to what you observed.*
8F3 *Yes.*
I. *What did you feel at that moment?*
8F3 *That my ideas were wrong. At some moments, I felt that I wasn't smart enough.*
I. *So, for you, the whole process made you feel bad.*
8F3 *Yes.*
I. *Did you feel puzzled?*
8F3 *Yes.*
I. *What was your first thought when you came across the problem with the four cylinders?*
8F3 *I felt that some of my ideas were wrong.*
I. *The ideas you had at the beginning have now changed. Do you think that there might be other factors affecting the phenomenon, which we did not examine?*
8F3 *Yes, I believe that there might be other factors affecting floating. I'm not sure that we have reached a solution.*

Participant 8F3 was reluctant to express her conceptions regarding the factors affecting floating/sinking. When she recognized the discrepancy and realized that some of her initial conceptions were alternative or could not provide an adequate explanatory framework for the solution of the problem, she felt uncomfortable and, according to the previous excerpt, she felt that she "was not smart enough." Therefore, participant 8F3 connected the problem situation concerning floating/sinking to stereotypes that she had regarding her cognitive ability, which caused her subsequent desire to disengage from the procedure of solving the problem. However, both of the students who demonstrated high level of anxiety managed to progress towards the scientifically accepted explanation of the phenomenon after the intervention.

Reappraisal of the Cognitive Conflict Situation

Subsequent to participants' involvement in the solution of the problem situation presented in Figure 2, they were required to compare between their initial and final conceptions and to identify any changes between their initial and final conceptions, in an attempt to self-report the reappraisal of their initial conceptions.

As presented in Table 4, all of the participants managed to perform cognitive reappraisal of the CC situation. However, the content and level of the reappraisal performed varied among subjects. More specifically, five out of the fifteen participants (4F1, 6M2, 8M2, 8F2, and 8F3) managed to self-report a total reappraisal, since they were able to identify the changes between their initial and final conceptions, whereas ten participants (4M1, 4M2, 4M3, 4F2, 6M1, 6F1, 6F2, 6F3, 8M1, and 8F1) could not clearly identify the content of those changes. Interestingly, five (4M1, 4M2, 4M3, 6M1, 6F3) out of the eight students who had managed to progress from more simplified towards the scientifically accepted explanation of floating/sinking self-reported that they had partially reappraised their initial conceptions, whereas only three (4F1, 8F2, and 8F3) of the students, who correctly conceptualize the floating/sinking phenomenon, reported that they underwent complete reappraisal of their initial ideas. The fact that the majority of the students, who progressed towards more sophisticated explanations of the phenomenon after the intervention, had only managed to self-report partial cognitive reappraisal, indicates that they might have been more consciously involved in each of the steps of the inquiry process. According to Barak, Ben-Chaim and Zoller (2007), students' involvement in real-world problems, open-ended questions, and inquiry-based experiments fosters the development of higher-order thinking skills required to identify the modifications occurring to students' conceptions after their involvement in a teaching intervention. The following excerpt describes a participant's reasoning (6F3), who managed to progress to the scientifically accepted explanation of floating/sinking and could self-report partial cognitive reappraisal.

I. *Would you like to understand further why some of your initial explanations were not accurate or was the explanation of the phenomenon clear in your mind now?*
6F3 *No, I would like to continue investigating floating/sinking.*
I. *What would you like to do?*
6F3 *I'd like to try some other experiments, easier than the ones we did to clarify certain things in my mind.*
I. *Could you give me an example of an experiment you would like to do?*
6F3 *It depends….*
I. *Are you convinced by the experiments we did?*
6F3 *Yes.*

As presented in Table 4, three (4F1, 8F2, and 8F3) out of the eight participants, who managed to progress to the scientifically accepted explanation of the phenomenon, reported a complete reappraisal of the CC situation. The three students not only managed to reach the scientifically accepted explanation, but they could also indicate the changes between their initial and final conceptions.

Additionally, all of the students who, after the intervention, did not change initial pattern of reasoning (4F2, 6F1, 6F2, 8M1, and 8F1) reported partial reappraisal of their initial conceptions. This indicates that students are often failing to accurately identify the changes between their initial and final conceptions. As a result, they usually report changes between their initial and final conceptions, but in reality they do not perform accordingly. According to Novak (2002), students' initial conceptions are resistant to change even after their involvement in specifically designed interventions. Thus, some students who report partial or total reappraisal of their initial conceptions, may remain unaffected or even regress in their ways of thinking. In these cases, students' self-reported evaluations of their cognitive reappraisal are far the reality. The following excerpt is part of the interview with student 8M1.

I. *At the beginning of the interviews you had some ideas. Did they change after the experiments we did?*
8M1 *Yes.*
I. *What changed exactly?*
8M1 *Through the experiments, I realized that something in my mind was wrong, because when we put salt in the cylinder the egg went up [was floating].*
I. *What do you mean by saying "something was wrong in your mind"?*
8M1 *Because now I see that the egg is at the bottom. Before, when we used salt, it went up.*
I. *What ideas do you have about Cylinder B?*
8M1 *Does it contain water?*
[…]
I. *Now would you like to further investigate why some of your initial ideas were not correct?*
8M1 *No, everything is now fixed in my mind.*
I. *Would you like to understand better why these eggs are in these positions in the four cylinders (Figure 2)?*
8M1 *No, I have been already convinced by the experiments we did.*

Finally, the two students (6M2 and 8M2) who, after the intervention, regressed from the *object-liquid hypothesis* towards the *liquid hypothesis* reported that they had total reappraisal of their initial conceptions. For these students, the whole process did not produce positive learning outcomes, since they did not indicate any progress in their understanding, although they reported that their final conceptions were more correct. According to Zohar and Aharon-Kravetsky (2005), research should focus on identifying the methods that most efficiently cause productive learning outcomes for specific groups of learners and tailor teaching interventions accordingly.

Implications

The present study attempted to explore the mechanism of CC and its potential to promote productive learning outcomes for elementary and middle school students. A floating/sinking scenario constituted the context of the study. Qualitative data concerning students' conceptions on floating/sinking was collected before and after an inquiry-based intervention, while students were also individually interviewed and were specifically asked to evaluate the cognitive (recognition of anomalous data and cognitive reappraisal of their initial conceptions) and affective components (interest and anxiety) of CC. Correctly understanding the floating/sinking phenomenon is a challenging task, because it requires correct understanding of density, together with a concrete model for systems involving other forms of balance and equilibrium (Waugh, 2007). Moreover, floating/sinking is a phenomenon usually experienced by the majority of students, who have most likely constructed their own, often alternative, explanatory frameworks for it. According to Yin, Tomita, and Shavelson (2008) existing conceptions can provide a good foundation for formal schooling for some individuals, whereas for others they may hinder scientific understanding. However, authentic learning experiences that engage students' minds enable them to become investigators, who actively construct their knowledge (Danko-McGhee & Slutsky, 2007).

According to Novak (2002), learning is a highly idiosyncratic event, depending upon the individual's approaches to learning, emotional predispositions, and prior knowledge. As the interview analysis of the present study revealed, CC is also an idiosyncratic event and may lead individuals to different learning outcomes. The teaching learning scenario provided ample opportunities for inducing CC during various stages of the data collection procedure, depending upon individuals' initial conceptions, interests, and level of cognitive development. In addition, the data collection procedure induced new cognitive conflicts for some students. Theses CCs were directly related to the inquiry learning that was implemented and the consequent the conversations that followed them. Some students initially demonstrated more scientifically adequate conceptions than the rest of the students, but, at the end of the procedure, they wanted to continue experimenting using various kinds of objects and other liquids, such as soft drinks.

The results of the study indicated that the majority of the students progressed towards a better conceptual understanding of the floating/sinking phenomenon through the implementation of the CC strategy. This was not however true for all the students, since some of them, after the intervention, regressed to more naïve conceptions in comparison with their initial conceptions. In a review of research, Vosniadou and Brewer (1987) claimed that the use of anomalies is an effective methodology of promoting knowledge acquisition in science domains. They also stated that although recognition of anomalies can serve as an important prerequisite for initiating cognitive restructuring, it is not by itself the optimal way of acquiring new knowledge. What promotes effective cognitive restructuring, according to Vosniadou and Brewer (1987) is the engagement of the child in Socratic conversations with the teacher. Roth, Anderson, and Smith (1986) also insisted that the teacher must be directly involved in diagnosing students' naïve conceptions and in presenting content in a way that is engaging and meaningful for students.

The overall results of the study clearly indicate that teaching and learning should move beyond cold cognition towards the integration of affective factors that seem to better foster cognitive engagement in learning and optimal cognitive reorganization of learners' knowledge. Besides, learning mechanisms, such as, cognitive conflict and cognitive restructuring could be more adequately understood through the examination of affective factors. Thus, these processes should be more systematically employed, without neglecting the affective domain, in an attempt to design and implement a better learning environment where learners are encouraged and motivated to be actively engaged in the learning process.

Final evaluation criteria

1. Ability to employ different techniques (i.e., individual and group interviews, questionnaires, etc.) for identifying learners‘ conceptions.
2. Ability to design and implement strategies challenging learners' conceptions (i.e., design experiments that constitute discrepant events for learners' conceptions).
3. Ability to design and implement teaching approaches that take into consideration learners' conceptions, and can foster conceptual understanding and growth.

4. Ability to encourage feelings of interest and motivation that can lead to cognitive engagement of learners.
5. Ability to guide group work and other forms of collaboration.
6. Ability to continuously implement formative evaluation strategies.
7. Ability to encourage the development of students' metacognition.

Strategies and techniques of evaluation

1. Electronic portfolios
2. Synchronous and/or asynchronous electronic discussions
3. Student projects
4. Other formative and/or summative evaluation techniques, such as, individual and group interviews, classroom discussions, questionnaires tests, etc.

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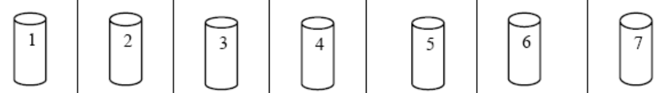
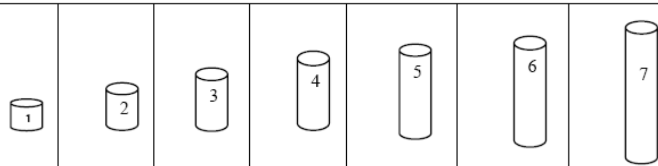
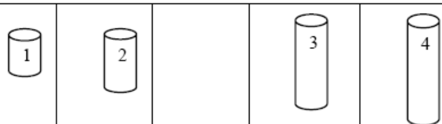
Appendix A

Three Sets of Closed Cylinders

(a) Mass Increases Progressively, while the Volume Remains Constant							
First Experiment							
Height	10.5 cm	10.5 cm	10.5 cm	10.5cm	10.5 cm	10.5 cm	10.5 cm
Diameter	3 cm	3 cm	3 cm	3 cm	3 cm	3 cm	3 cm
Mass	**60 g**	**70 g**	**80 g**	**85 g**	**100 g**	**110 g**	**115 g**
(b) Volume Increases Progressively, while the Mass Remains Constant							
Second Experiment							
Height	**5 cm**	**6.5 cm**	**9 cm**	**10.5 cm**	**12.5 cm**	**14.5 cm**	**16.5 cm**
Diameter	3 cm	3 cm	3 cm	3 cm	3 cm	3 cm	3 cm
Mass	85 g	85 g	85 g	85 g	85 g	85 g	85 g
(c) Four Cylinders with Different Volume and Different Mass							
Third Experiment							
Height		**6.5 cm**	**9 cm**		**12.5 cm**	**14.5 cm**	
Diameter		3 cm	3 cm		3 cm	3 cm	
Mass		**100 g**	**60 g**		**70 g**	**110 g**	

Floating and Sinking of an Object in a Liquid – Based on Socio-cognitive Constructivism

Training material for students

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