

Article

Existing and Emerging Students' Alternative Ideas on Geodynamic Phenomena: Development, Controlling Factors, Characteristics

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Abstract: This paper studies Greek junior high school students' alternative ideas, both initial and synthetic, on geodynamic phenomena. It comments in detail on students' concepts on Earth structure, earthquake occurrence, volcano formation, and relief change. Additionally, it attempts to trace and interpret how and why these ideas form (concept development), presenting that initial and synthetic ones are indissolubly attached and utterly directed by environmental interaction. Data analysis verifies that curriculum inadequacy and false scientific terminology in textbooks enforce the generation of alternative ideas. New synthetic alternative ideas on geodynamic phenomena are presented which are mainly characterized by intermittent and fragmentary perspective. Furthermore, the characteristics of both initial and synthetic alternative ideas are outlined, giving emphasis on the facts that students represent geodynamic phenomena as instantaneous events and that they are able to describe the repeatability of the phenomena, but they show difficulty in capturing their continuity. Finally, more factors that control alternative idea development on geodynamic phenomena are highlighted—such as (i) lack of continuous thinking, (ii) distribution, intensity and frequency of geodynamic phenomena, and (iii) current affairs (i.e., pollution, technology evolution, human intervention)—hoping that their revelation will lead to alternative ideas' decomposition and thus to pure scientific knowledge.

Keywords: alternative ideas; students' concepts; concept development; geodynamic phenomena; geoscience education



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1. Introduction

Earth science literacy is restricted worldwide [1–9], despite the expanding impact of Earth processes on humans such as natural hazards, climate change, and geodynamic phenomena. Thus, enhanced Earth science education is necessary. Over the last decades Earth scientists have conducted research to explore students' alternative ideas on geodynamic phenomena [10–31], in order to enhance Earth science learning.

Emerging student concepts on Earth structure and geodynamic phenomena are on the rise. Students express ideas such as the notion that magma originates from the Earth's core [15,32–34], or that the magma supply for volcanos comes from the inner core [21]. Additionally, all volcanos are believed to produce lava when erupting [32] and eruptions result from global warming [31]. Students also claim that earthquakes are triggered by weather and global warming [34] or generally by heat, climate, people, animals, gas pressure, gravity, rotation of the Earth, 'exploding soil', or volcanos [20]. It is noteworthy to explore why students consider tectonic plates as static [9,31] and are situated somewhere below the surface [20].

In aspects of causality, students find it difficult to conceptualize the cause perspective of Earth science. According to Licona et al. [24], it is usual to face difficulty in differentiating between the cause of a geologic phenomenon and its effects. For example, students describe

the effects of an earthquake rather than the cause when they are asked about earthquake occurrence. Additionally, they often claim that tsunamis can cause an earthquake. What is also common is that students do not communicate any form of full understanding of the causes of earthquakes and volcanos. For instance, they often consider that volcanos are created by heat while the Earth's core generates earthquakes. Students struggle to apprehend the cause of plate movement [22,24]. On the contrary, Vergara-Diaz et al. [31] propose that advanced students can recognize plate tectonics as the cause of a dynamic Earth. However, according to Libarkin et al. [20], students might acknowledge underlying causes for geoscience subjects or might use scientific terms in phenomena explanation, despite the fact that they are not clearly understood.

As far as process conceptualization is concerned, Chi et al. [35] and Libarkin et al. [20] maintain that students view the world as "a set of matter" and find it difficult to conceive the process aspect. Although abundant literature exhibits students' conceptual background and cognitional map on Earth science, more research is required on the nature and origin of these concepts [19].

Educational scientists recognize that the presence of alternative ideas in students' conceptual frame impedes the achievement of conceptual change [16,36–38]. Thus, it is proposed to focus on the way these ideas will be transformed [39–41], in order to facilitate conceptual change [42].

Some misconceptions are, unfortunately, quite robust and persistent [43]. Initial alternative ideas bear high resistance even after a complete teaching procedure [20,36,38,44], or after the usage of analogue teaching models [45]. Thus, not only are they not easily abandoned, but also incoming information is assimilated, leading to the formation of mixed ideas [46], or synthetic mental models [47,48]. Other students incorporate scientific terminology into their cognitional framework without accomplishing conceptual change and considering it as the correct learning process [49]. Chi [43] attributes the persistence of some misconceptions to the miscategorization of the concepts into the wrong ontological level.

The factors that lead to the development of alternative ideas are still being investigated. So far, the determinant factors include direct observation absence, abstract concepts, usage of everyday language in scientific topics, changing definition, terminology oversimplification, overlapping concepts, mechanical learning, textbook stereotypes and insufficient previous knowledge, rote learning, use of analogies [16,20,38,44,50], etc. Unfortunately, misconceptions can be influenced by social and cultural parameters—i.e., supernatural forces, myths [18,51,52], as well as by psychological, cognitional, and environmental ones such as TV, newspapers, magazines, media, parents, friends, books, textbooks, teachers, and secondary school curricula [5,15,18,20,33,53].

A disappointing finding for geoscience education is the low science content level of textbooks [4,7,8,54]. King et al. [5] revealed errors and oversimplifications of scientific concepts that alter the real meanings within the curriculum. These errors are assumed to discourage teachers and guide them to wrong interpretations of the phenomena [5], resulting in the formulation of their alternative ideas, which are disseminated to students through instruction. According to McDonald et al. [30], instructional cause is the main source responsible for most of the students' misunderstandings in ESS due to their few everyday experiences with ESS phenomena, like plate tectonics. What students understand or misunderstand is more likely to root from instructional patterns rather than students' inability to apprehend more complicated concepts. Specifically, McDonald et al. [30] report that the building approach part-to-whole generates reverse cause understandings when teaching ESS phenomena to students. For example, when volcanos and earthquakes are taught individually at first and later on integrated to plate motion, then it is most likely for students to consider plate motion as the result of volcanos and earthquakes (events). Furthermore, the fact that some features like mountains are presented as static and not as dynamic ones generates ontological confusions. The same authors continue, for instance, when mountains are only presented in terms of erosion and not of their formation, then students misattribute plate motion to erosion, water, currents, waves, climate change, etc.

Capps et al. [33] highlighted the important role of language knowledge and reading fluency. Specifically, it was reported that new student readers found it difficult to read quickly the TV program subtitles. So, students had partial comprehension of the scientific information supplying their conceptual gaps with their conceptions and thus generating alternative ideas.

Francek [34] and Dolphin and Benoit [9] defended the notion that students' misconceptions on tectonic plates came after the use of the common word "plate" (i.e., dinner plate). They documented that students automatically and unconsciously transferred the characteristics of the ceramic plate to the target concept, which is the lithospheric plate. Therefore, tectonic plates can be 'stacked up' under the ground, cannot bend, and their edges can break when they hit onto each other just like ceramic plates do. So, students could not ascribe elastic properties to the plates but only brittle, because automatic mapping of dinner plate onto lithosphere hid the elastic properties.

It is obvious that more in depth research on concept construction in Earth science is indispensable. All these data stimulate the scientific community to conduct new research in order to expose how some factors prevent the progression of scientific knowledge and favor the creation of alternative conceptual frameworks. Hence, the present paper attempts to analyze the ways that some initial and synthetic alternative ideas for geodynamic phenomena (such as Earth structure, earthquake and volcano formation, and relief evolution) are constructed and focuses on their characteristics and on the factors controlling their development as well. The purpose of this paper is to shed light on how some alternative ideas are delivered, because unravelling the procedures of their formation will lead to their deconstruction and thus to the achievement of conceptual change.

2. Methods

For research purposes, an open-ended questionnaire tool was designed in order to reveal students' ideas on geodynamic phenomena. Open-ended questions were preferred because we believe they can reveal extensive details on students' concepts [55,56]. Close-ended questions offer standardized answers and may use scientific terms, facts that can direct students' answers [55,57]. A pair of 'question-control question' was implemented for each didactic goal, in order to check the coherence of students' answers [56]. These pair questions are depicted in Figure 1 with the same code name but numbered as 1 and 2 (i.e., Earth Structure 1, Earth Structure 2). Close-ended questions were only used as control questions just in a few cases in order to specify their reliability.

The questionnaire tool was validated through the following steps: (i) one geoscientist constructed the questions according to the scientific goals of the research, (ii) two geologists verified the content validity of the questions, (iii) two expert science educators attested for the achievement of construct validity, (iv) two school science teachers inspected the questions for the communication validity, (v) the questionnaire tool was piloted to three A grade classes of the same junior high school with 21, 24, 25 students respectively, as well as a group of 10 students, randomly selected, were interviewed to assure communication and construct validity. (vi) After the necessary amendments, the tool was finally repiloted to three A grade classes of another junior high school to avoid communication between students and biased answers, so that content validity could be verified. (vii) Furthermore, the questionnaire tool was applied to A grade class in three different schools so as to perform the reliability assessment. We paid great attention so that the questionnaire took place under the same circumstances for all A grade classes even in different schools. (viii) In the end, the final version of the questionnaire tool (Table 1) was implemented on a sample of 218 students at three A grade classes of 4 different public junior high schools in Greece. Sex distribution performed almost equally with $\chi^2 = 14.595$, $df = 2$ and $p = 0.001$. Females corresponded to 55.30% versus males who corresponded to 44.70% of the sample. Students' age ranged between 12–13 years old. The implementation lasted not more than one month so as to maintain internal validity.



Figure 1. Scientifically accepted (correct) and not accepted (wrong) students' answers to questions on geodynamic phenomena. (Full questions are presented in Table 1).

Table 1. Earth: A living planet. Final version of the questions to the questionnaire tool applied to the sample of 218 students.

-
1. Describe what you believe there is under the ground we stand on deep deep inside. (Earth structure 1)

 2. Could you dig a hole so deep into the Earth that you reach the other side of it? Yes, No, I don't know. Explain your opinion. (Earth temperature 1)

 3. If you could go on a journey deep inside Earth how would you feel? (i) cold, (ii) hot, (iii) something else. (Earth temperature 2)

 4. Draw a sketch to show how you imagine the Earth is underground deep down inside the Earth. Name or explain the parts of the Earth you have drawn. (Earth structure 2)

 5. Would you compare Earth to (a) an onion, (b) an orange, (c) an egg, (d) something else?

 6. What happens to make earthquakes occur? (Earthquake generation 1)

 7. How do you believe we could stop earthquakes from happening? (Earthquake generation 2)

 8. Russia or Greece is more probable to suffer from an earthquake? Why? (Earthquake distribution 1)

 9. How do you imagine that volcanos are created? (Volcano formation 1)

 10. Is lava that bursts out of a volcano being created at the time of explosion? Yes, No, I don't know. (Volcano formation 2)

 11. How do you believe we could stop volcanos from happening? (Volcano formation 3)

 12. Can we meet volcanos in Greece? Why? (Volcano distribution 1)

 13. If you could travel in the future million years after, how can you imagine the relief of your country would be? The same or not? Why? (Relief change 1)

 14. How do you think that mountains have been formed? (Mountain formation 1)

 15. Do you believe that mountains will be formed again in the future? Explain your opinion. (Future mountain formation 2—Relief change 2)

 16. The Mediterranean region is going to be different in a few million years. How do you think it will look like and why? (Plate movement Mediterranean—Relief change 3)

 17. The journey between Europe and America will last longer after a few million years in the future. Could you explain why? (Plate movement—Europe—America)

 18. If Earth core was hollow, then could earthquakes occur? Why? (Correlation of inner Earth structure to Earth surface-empty core)

 19. If the inner part of Earth was frozen, then could mountains be formed? Why? (Correlation of inner Earth structure to Earth surface-frozen core)

The answers to the questions were encoded according to the Content Analysis method after Kerlinger [58]. Data were elaborated using IBM SPSS software v.22 and crosschecked using frequency tables, diagrams, and statistic modes offering us many qualitative and quantitative findings, some of them presented herein.

3. Curriculum and School Textbook Evaluation

The survey necessitated the evaluation of the geography curriculum and the geography textbook of A class students in junior high school as well as the primary school geography textbooks of the Greek educational system [57], with regards to geodynamic phenomena. Indicative points are reported right below.

The main drawback of geography curriculum and textbooks of A class in junior high school is that geodynamic phenomena are studied individually and not as interrelated facts within the geosystem [59], which may drive to undesirable concept frameworks like the reversal of cause [30].

The textbook of 6th primary school class in the unit of natural disasters and their effects on human life: (a) compares Earth structure to an onion with no description or illustration of it at all, and (b) acknowledges that earthquake and volcano formation is thoroughly attributed to plate collision.

Additionally, in the unit of shoreline structure formation (gulfs, peninsulas, islands, etc.) it is described, 'The geological procedures (earthquakes and volcanos) that happened millions and billions before in the Balkan Peninsula resulted in the formation of not only intense shoreline structures (peninsulas, gulfs, capes etc.) but numerous islands, too, like in Greece and Croatia'. The textbook phrasing not only implies that earthquakes and volcanos are the geological procedures responsible for relief and island formation, but it also fuels the notion that Earth relief is the result of surficial processes, ignoring deep ones. In addition, the use of past tense 'happened' breeds the aspect of stability and not of continuity in geological processes. It is even disastrous to claim that the islands of Balkan peninsula were formed millions and 'billions' of years ago.

In the 1st class primary school dictionary, an apparently wrong definition of volcano is exhibited: '*Volcano is a mountain which bears a hole on top of it, named crater. Lava coming from the centre of Earth bursts out from it*'. It is crucial to comment on the phrase '*Volcano is a mountain*', which directs students to create the concept that volcanos are formed just like mountains. Simultaneously, the phrase '*coming from the centre of the Earth*' prompts students to believe that lava comes from the Earth's core.

Astonishingly, in the Greek mathematics textbook of the 6th class of primary school, to the unit of stable and variable amounts in an exercise is documented that *The Olympus Mountain height is stable*, which navigates students to the belief of mountain and relief stability.

Thus, Greek geography and mathematics school textbooks contain conspicuous errors and oversimplifications, just like school geoscience textbooks in other nationalities such as in Spain [8], the UK [5], and USA [54].

4. Results of Data Analysis

After the implementation of the questionnaire, we performed qualitative and quantitative analysis of the students' answers on geodynamic phenomena. Figure 1 depicts the percentages of scientifically accepted answers, not scientifically accepted answers and 'I don't know/I don't reply' answers. Scientifically accepted answers record especially low percentages, even close to zero. On the contrary, not scientifically accepted answers display high percentages compared to the former. 'I don't know/I don't reply' answers show as high percentages as not scientifically accepted ones. These data, along with the qualitative analysis of students' answers, frame a general picture of A class junior high school geoscience level which implies that students graduating from Greek primary school lack basic geoscience knowledge, confuse geoscience concepts and bear plenty of alternative ideas.

Two cases diverge from the rest of the recordings (Figure 1): the scientifically accepted answers to 'Inner Earth temperature 2' and 'Volcano formation 2' close-ended control questions record especially high percentages comparatively to their open-ended pair questions ('Inner Earth temperature 1' and 'Volcano formation 1'), which present far lower percentages. This finding verifies that close ended questions can control students' answers [57] and offer divergent data. Below we provide an indicative qualitative and quantitative analysis of students' alternative ideas in detail.

4.1. Earth Structure

Students' earth structure alternative ideas are summarized in Figure 2 and we emphasize four cases. An unexpectedly high percentage of students insists on horizontal Earth layering despite the vast amount of information on Earth structure they receive from multiple resources (books, internet, and school). It is an initial concept that students compose after their own observation that the ground they live on seems to be horizontal (optical stimulus) no matter what.

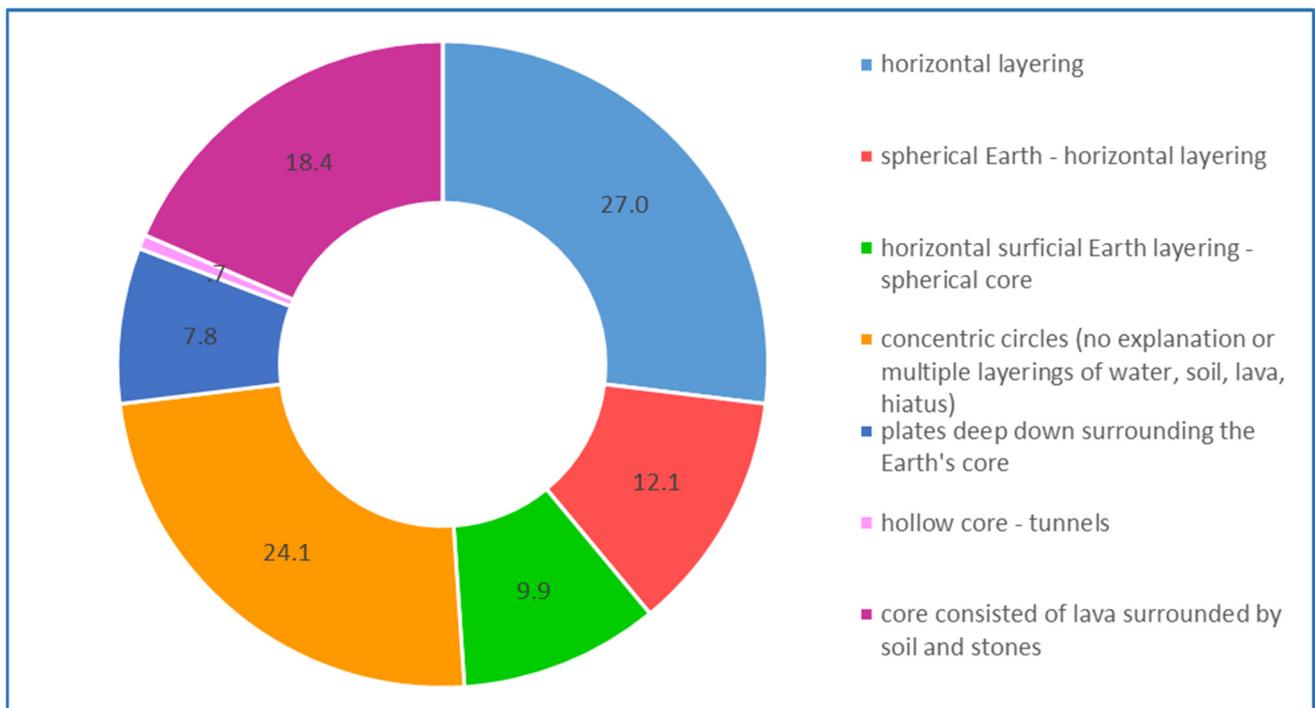


Figure 2. Students' alternative ideas on Earth structure. (Answers to question 4 in Table 1).

Another interesting and frequently drawn concept is that Earth structure consists of concentric circles (Figure 3), which students: (a) show cognitional weakness of defining, (b) describe as multiple alternations of water, soil, lava, hiatus, ores, etc., or (c) compare to an onion (resembling Earth structure to an onion) without further explanation (Figure 4b), just like the Greek primary school textbook describes as mentioned above.

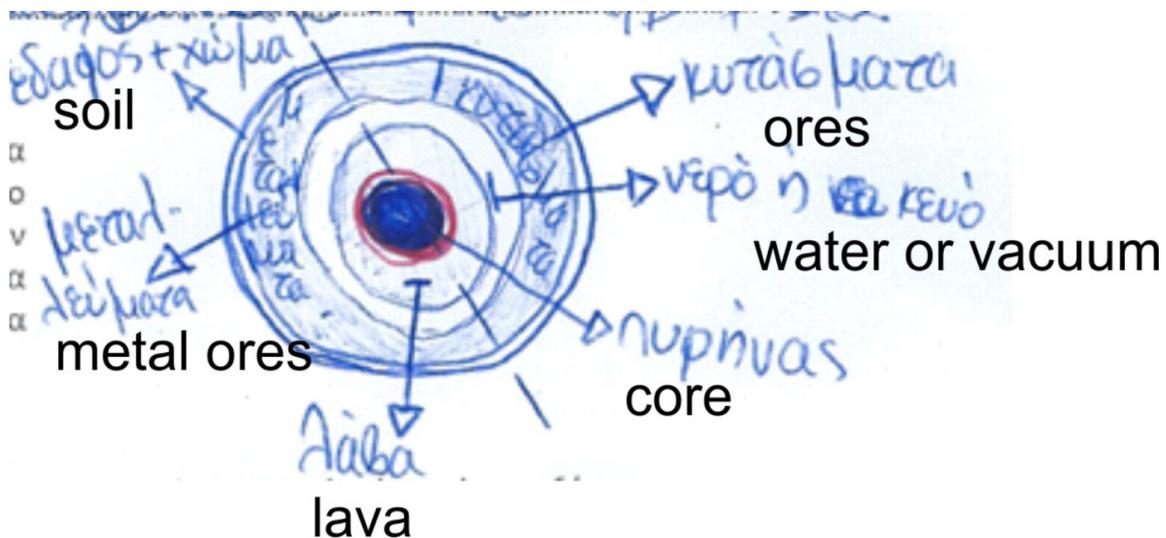


Figure 3. A student's concept about inner Earth, which is structured by concentric circles. (Sketch to question 4 in Table 1).

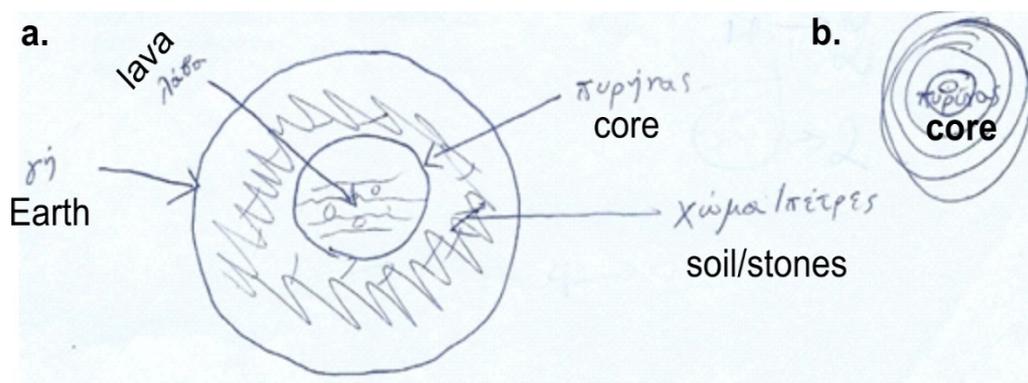


Figure 4. (a,b) Two different concepts about Earth structure expressed by the same student. (Sketch to question 4 in Table 1).

The third worth-mentioning alternative idea represents the notion that the core is usually made of lava and is surrounded by soil and stones (Figures 4 and 5). In Figure 5, the student believes that inner Earth consists of soil of huge thickness which encloses a vast amount of water depicted in horizontal waves. The concepts of soil, water, and horizontal layering come directly from natural environment (humans are familiar to these concepts from their birth), formulating thus initial alternative ideas. However, the student has also been exposed to the concept of spherical core and spherical Earth shape, probably from school or media. So, the student tried to incorporate these new concepts to his/her initial ones resulting in the synthetic alternative idea drawn in Figure 5: meaning a spherical core floating in horizontal moving water surrounded by soil of huge thickness in a spherical Earth.

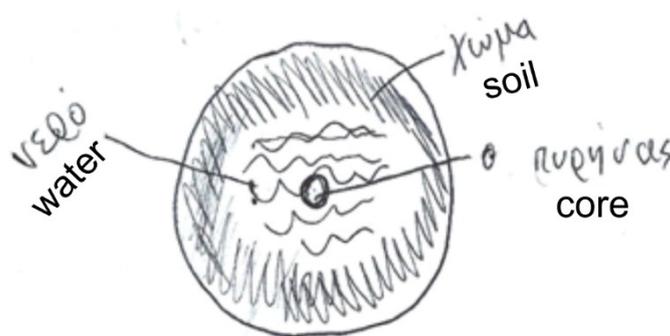


Figure 5. Another student believes that the core floats within horizontally layered water in the center of the Earth. (Sketch to question 4 in Table 1).

Similarly, in Figure 4a, another student's synthetic alternative idea is also drawn. The student sketches a spherical core (incoming information) which is filled with lava (incoming information from the primary school dictionary) with horizontal layering (initial concept-direct observation from supposed horizontal ground). The core is surrounded by soil/stones (initial concept from immediate optical stimulus obtained from natural environment) of enormous thickness within a spherical Earth (incoming information). Nevertheless, the student is not certain about the explanation he/she presents in Figure 4a. Thus, the same student makes a second, alternative description in a smaller sketch (Figure 4b). The fact that the sketch is smaller than the first one is assumed to imply his/her insecurity about the latter case, too. In that case, (Figure 4b), the student compares inner Earth structure to an onion, just like the geography primary school textbook. This occasion verifies the confusion that prevails in the student's conceptual frame on geodynamic phenomena, as mentioned in the introductory paragraph of the results. It is apparent that this confusion is founded on the fact that geodynamic structures and procedures cannot be observed in the surrounding environment and hence visualized by people due to their spatial and time scale, as is already mentioned by Love [26] and Orion

and Ault [60]. Additionally, when students offer two alternative cases in their responses, just like our occasion, Siegal et al. [61] argue that these students depict incoherence or fragmented “knowledge”, because they hold both intuitive concepts and scientific information which are not interconnected.

Another new synthetic alternative idea that students came up with in this research is the horizontal surficial Earth layering (initial concept) with a spherical core (incoming information) underneath, reaching 9.9% (Figure 2). Here, the persistence of initial idea of supposed ground horizontality (every day optical stimuli) is obvious, despite the incoming scientific information of the spherical Earth. On the contrary, the incoming information of spherical core is easier accepted than the spherical Earth shape by the students because the optical stimuli of the core is absent. It is obvious thus that everyday optical stimuli and environmental interaction is stronger than sporadic incoming information by teaching or media in concept generation.

4.2. Earthquake Occurrence

Students hold many alternative ideas on earthquake generation (Figure 6), most of which are mentioned in international literature (e.g., [10–12,15–18,20,22,32,34]). In this paper, we comment on two outstanding cases.

Regarding the question ‘What happens to make earthquakes occur?’, 24.2% of the students replied using exactly the terminology ‘Plate collision’ without any explanation, a phrase recorded in the 6th grade primary school geography textbook.

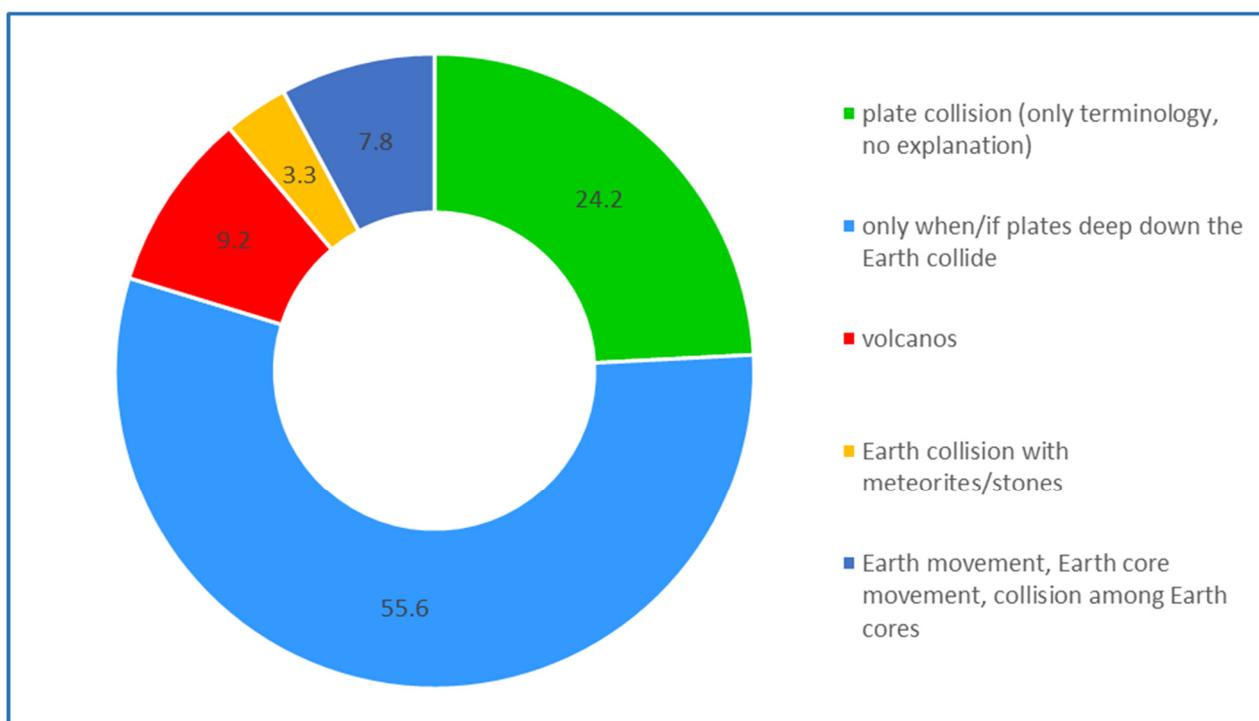


Figure 6. Students’ alternative ideas on earthquake generation. (Answers to question 6 in Table 1).

More than half of the students (55.6%) attribute earthquake formation to two plates within or underneath Earth (Figure 7). Specifically, students mention that ‘When these two plates collide, only then an earthquake can occur. Then, plates pull apart again and stop moving. When plates start moving and collide again, then an earthquake will occur’. Apart from the plates’ position (under Earth surface and usually near or inside the core), it is also noteworthy that students consider plate collision as an instantaneous procedure and not as a long term one. They describe the collision duration as very short and resemble plate collision to colliding cars in a funfair. So, students show clear insufficiency in grappling

with the continuity of plate movement and we believe it is so because they correlate plate movement to earthquake occurrence, an instantaneous event. Additionally, students describe that collisions are repeatable events, just like earthquakes. Similarly, McDonald et al. [30] refers to the intermittent plate motion of students' understanding.

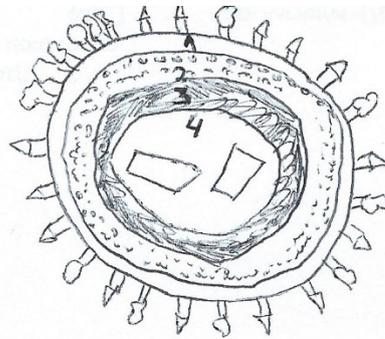


Figure 7. Another student depicts two plates within Earth center, which collide and cause earthquakes. (Answers to question 6 in Table 1).

We should also mention that one out of ten (9.2%) students attribute earthquake occurrence to volcano formation.

Regarding a similar question in the questionnaire 'If Earth core was hollow, then could earthquakes occur? Why?', some students express an interesting concept which holds that 'Plates can move and provoke earthquakes even if the Earth core is empty or cold', presenting a misattribution of cause of plate movement, too. It also depicts students' insufficiency, ignorance, or unsuitable training to (a) correlate surficial phenomena such as earthquakes to the inner Earth, a perspective also delivered into the curriculum as mentioned above, (b) tackle with process thinking, and (c) search for the cause of the phenomena. These findings seem to be logical and are assumed to be the result of the association of huge incoming media information and poor school instruction, including severe mistakes in school textbooks. This incongruence may offer students the tinder to create their own concepts leading to the construction of such alternative ideas. We do not support that school instruction should supply advanced knowledge, but it should definitely be enhanced in alignment to each school grade/age level.

4.3. Volcano Formation

Students' alternative ideas on volcano formation are presented in Figure 8, from which we outline three cases. In the first one, a high percentage of students (31.2%) attributes volcano formation to earthquake occurrence, while 9.2% of students claim that earthquakes occur due to volcanos (Figure 6). At this point it is worth mentioning that the vast majority (89.8%) of students believe that there are no volcanos in Greece, while 8% believe that Santorini island is the only volcano in Greece and think of it as inactive (Figure 9). Furthermore, 38.3% describe Greece as a highly earthquake prone country (Figure 10). These concepts along with their percentages reveal that Greek students' conceptual frame on geodynamic phenomena is more influenced by seismic rather than volcanic activity. We assume it is due to the high seismic activity in Greece, its severe results, and its social, psychological, and economic impact on humans and especially on children.

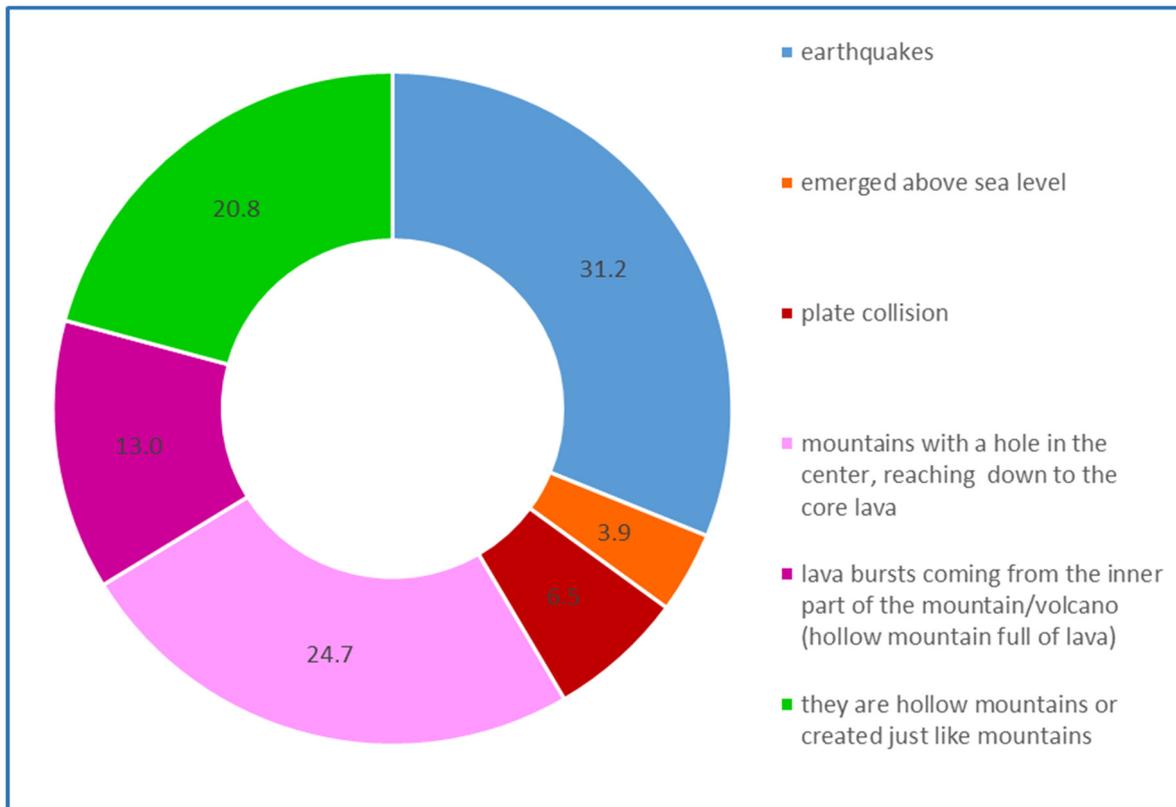


Figure 8. Students' alternative ideas on volcano formation. (Answers to question 9 in Table 1).

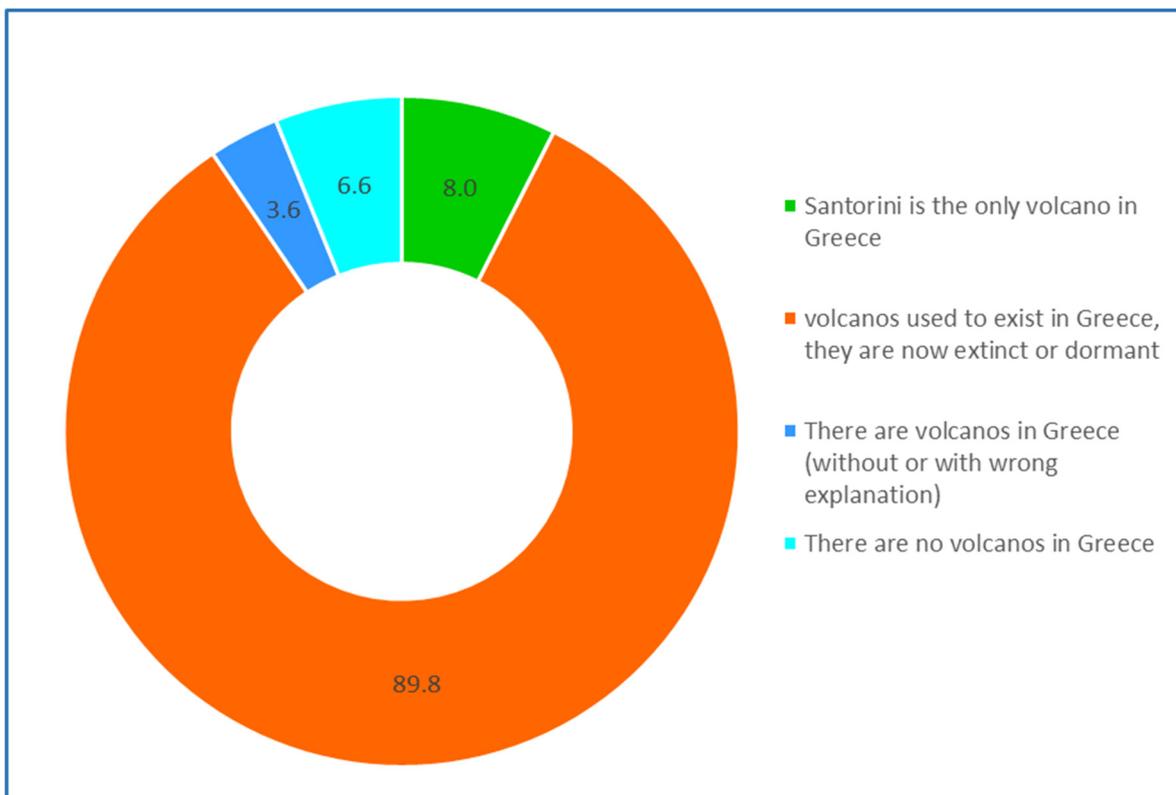


Figure 9. Students' alternative ideas on volcano distribution in Greece. (Answers to question 12 in Table 1).

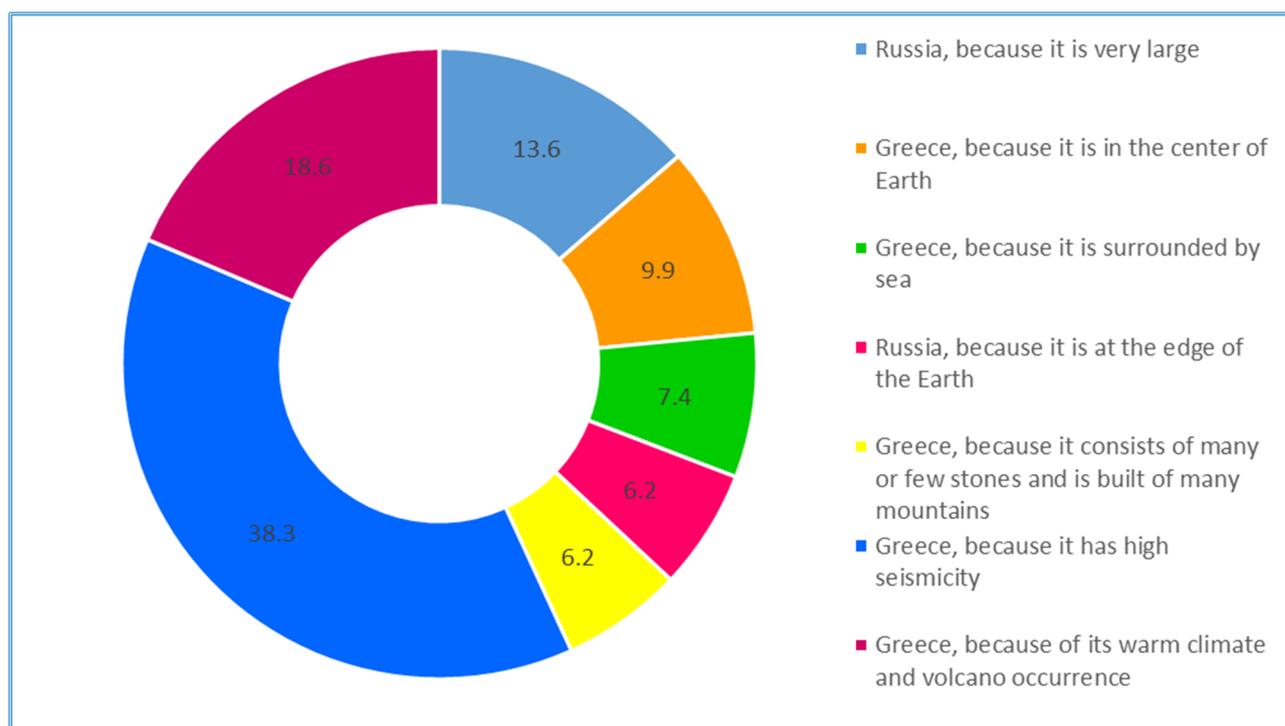


Figure 10. Students' alternative ideas on earthquake distribution. (Answers to question 8 in Table 1).

On the contrary, according to Wang et al. [22], Singaporean students attribute both earthquake and volcano occurrence to magma. We suppose it is so because of Singapore's proximity to the "ring of fire" and volcano impact on humans is probably more intense. Ross and Shuell [11] believe that students in Utah, USA, attribute earthquake occurrence to volcano formation because it is geographically closer to volcano areas. While Aydin [62] noted that the Marmara earthquake in Turkey (1999) influenced students' earthquake concepts. Thus, we assume that the density and distribution of geodynamic phenomena in time and place where people live can determine the kind and the way of alternative ideas' that occur.

In Figure 8, to the question, 'How do you imagine that volcanos are created?', a low percentage (6.5%) of students replies using once more only the term 'By plate collision', exactly as described in the geography primary school textbook. A similar case has been mentioned before in the earthquake occurrence conceptions. One fourth of students (24.7%) insist that volcanos are mountains with a hole from top to the center of Earth, from where lava comes up and bursts out. This concept coincides with the volcano definition in the dictionary of Greek primary school. These last two cases show the misconceptions that can develop in students' conceptual frame by false scientific information in school textbooks. King et al. [6] estimated a mean level of one Earth science error/misconception per page in high school science textbooks over a survey in England and Wales. These errors coincided with the misconceptions that college students and science teachers bore. Therefore, it was assumed that published materials with errors reinforced the misconceptions in teachers and their students [7].

Another interesting concept is that volcanos form just like mountains (20.8%), while just previously we recorded students' ideas attributing volcanos to earthquakes and vice versa. These perplexing concepts confirm the confusion that prevails in students' conceptual frame as far as mountain, volcano, and earthquake formation are concerned and their struggle to manage within the context of causal procedures. Additionally, it is not accidental that this 20.8% approximates the 24.7% in the previous paragraph supporting the influence of wrong definitions.

4.4. Relief Change

As far as surface relief change is concerned, 32.6% of students accept that the relief changes without, however, being able to justify their answer (Figure 11). According to 13.5% of students, relief change is attributed to air temperature rise, to consequent ice melting, and thus to sea level uplift. The same students believe that this will cause the Mediterranean Sea to flood and expand in the future. This idea shares a resemblance with students' concept that plate movement depends on climate change, therefore the Atlantic Ocean is a kind of valley which has been filled with sea water because of sea level rise [30]. Other students (17.4%) attribute relief change to garbage accumulation, pollution, technology evolution, and generally human intervention. We believe that students are 'forced' to point out these parameters as relief change controllers—though they are not Earth associated—because these parameters are broadly presented through media and news in our everyday life (current affairs), affect our lives directly or indirectly, are social-centered and are usually human controlled. All these in terms of optical stimuli absence of geodynamic phenomena amplify this enforcement. Similarly, students in USA claim that plates move on account of surface events (hurricanes, meteors), features (air, water, glaciers), and human impact according to McDonald et al. [30]. Thus, it is obvious that these parameters definitely configure students' alternative ideas and therefore their conceptual frame, apart from social, cultural, psychological, cognitional, and environmental [15,17,18,22,47,51,53].

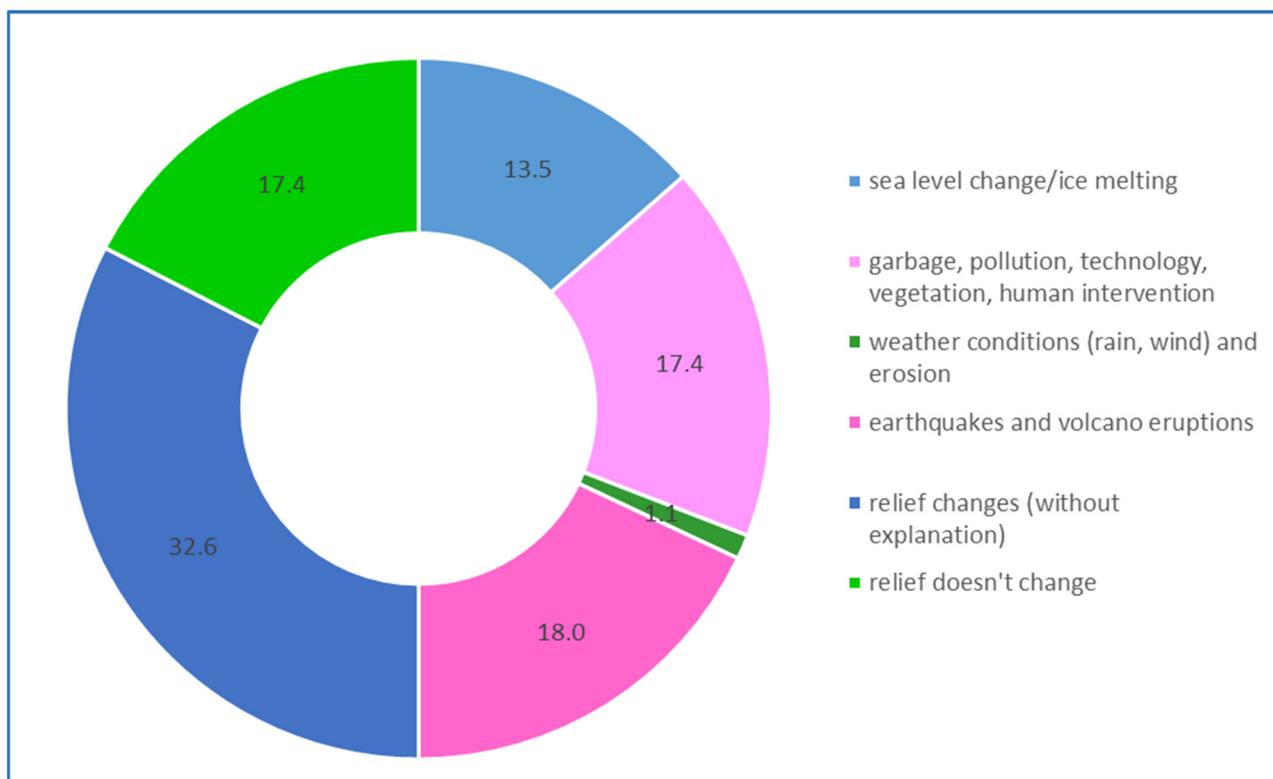


Figure 11. Students' alternative ideas on relief change. (Answers to question 16 in Table 1).

It is stimulating that 18% of students attribute relief change to earthquake occurrence. This is in accordance with the concept in Figure 10, recording that Greece is a high seismicity prone country, while, as already mentioned, 31.2% attribute volcanos to earthquakes (Figure 8). All these percentages strengthen the finding that high seismicity in Greece and its consequences affect students' conceptual development on geodynamic phenomena. Finally, some 17.4% insist that relief never changes. Unfortunately, this concept of stability has still remained in Greek textbooks as documented for the Balkan peninsula formation

(geography textbook) and the height of mountain Olympus (mathematics textbook) in previous paragraph.

We focus on three initial alternative ideas of students, about whether mountains can be formed again in the future or not (Figure 12). Exactly one in three students (33.3%) states that mountains can be either destroyed or reformed by earthquakes verifying the finding about the correlation between concept construction and earthquake occurrence proximity. Although 22.8% insist that mountains will be reborn by volcano explosion in the future. It is not a coincidence that mountain and generally relief formation is highly attributed to earthquakes and volcanos, exactly as the Balkan peninsula relief is claimed to be formed by the geological processes (earthquakes and volcanos) in the geography textbook. Furthermore, 29.8% of students proclaim that mountains are not going to form again in the future and they are deeply rooted. Finally, 10.7% reply that mountains can reoccur in the future (instantaneous event) only when plates move again in the future (instantaneous event). This concept is identical to the aforementioned idea that an earthquake can occur only if/when plates collide in the future. Thus, it validates the finding that students ignore the continuity of geodynamic phenomena and consider them as instantaneous and separate events. This ignorance might derive from either inherent but natural disability due to age level or unproper geoscience education, transmitted for instance by the textbooks of primary school.

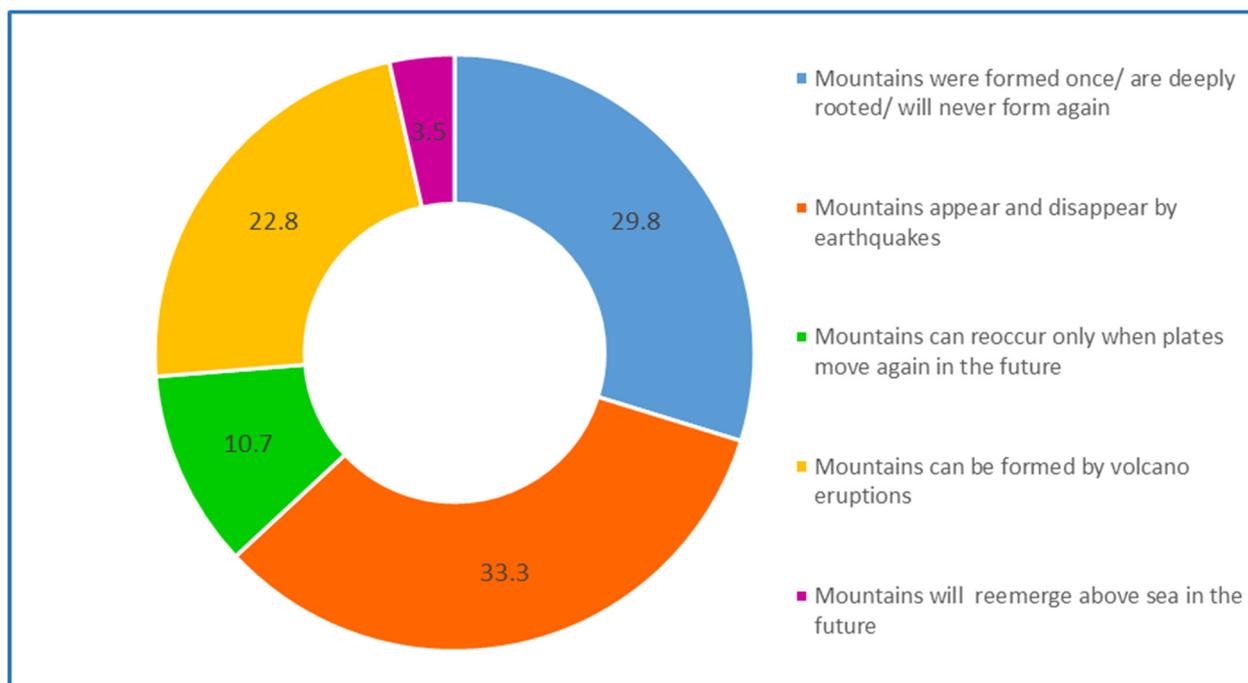


Figure 12. Students' alternative ideas on future mountain formation. (Answers to question 15 in Table 1).

A question in the questionnaire of the study asked: 'The journey between Europe and America will last longer after a few million years in the future. Could you explain why?' Despite the declaration that the trip will last longer, about 86.2% of students rejected this declaration proclaiming (Figure 13):

- i. The Atlantic Ocean is becoming narrower because continents will be rejoined in the future and the trip will last shorter (13.7%). It is apparent that students' conceptual frame is controlled by their exposure to videos or information referring to the tectonic plate reunion in the future. Secondly, overwhelming incoming information can lead to data misinterpretation, misunderstanding, and therefore to false concept development.

- ii. Almost three out of four (72.5%) insist that the distance between continents remains unchanged, because continents cannot move, and supplement that the trip will be shorter due to the technological evolution of transport means. This concept verifies the previously mentioned points on relief stability and technology evolution (29.8% in Figure 12 and 17.4% in Figure 11). Furthermore, the confusion between continent and plate is highlighted, as students assume that plates coincide with continents.

4.5. Terminology

In the present research, terminology usage and concept comprehension by students was also evaluated, as shown in Figure 14. We focus on the 34.4% of students, which represents an extensive usage of scientific terminology. However, the terms are usually mispronounced, falsely used, and falsely described, facts that prove lack of concept comprehension. It is obvious that this high percentage (34.4%) displays students' belief that learning is the memorization of scientific terminology, a fact that disorients them from real and deep learning procedures. It also indicates the extended terminology usage in textbooks, which is usually either partially (or not at all) explained or too specialized for this age level. This extended, but partially explained, terminology usage by textbook writers could be attributed to (a) their expertise, (b) their probable ignorance of students' cognitional level and alternative ideas, (c) their inadequacy or ignorance of the necessity that scientific information must be transformed and adjusted to students' cognitional and age level, and (d) their ignorance that scientific terms might hold a different meaning for them as for the novices due to conceptual metaphors [9]. Consequently, students are driven to prefer the easy way of terminology memorization than searching for concept meanings and the causes of phenomena, which are brain consuming processes, neglecting understanding. Thus, for example, Greek students frequently use the terminology 'Plate collision' to justify many of the geodynamic phenomena without being able to explain or describe the concepts. Accordingly, Libarkin et al. [20] claim that many students use scientific terms such as magma, mantle, core, lithosphere, plates, or even plate tectonics, which they are unable to explain. They also report that early high school students are exposed to geoscience concepts and terminology, but most demonstrate incomplete understanding. Finally, they conclude that incorporation of scientific terminology into an explanation does not necessarily imply understanding, a conclusion that supports the findings of this research. Furthermore, Dolphin and Benoit [9] elucidate how conceptual metaphors can lead to the construction of misconceptions by utilizing common terms—words—from the mesocosm (plate) in scientific phrases (tectonic plate) and thus unconsciously transferring properties from the source to the target of the analogy.

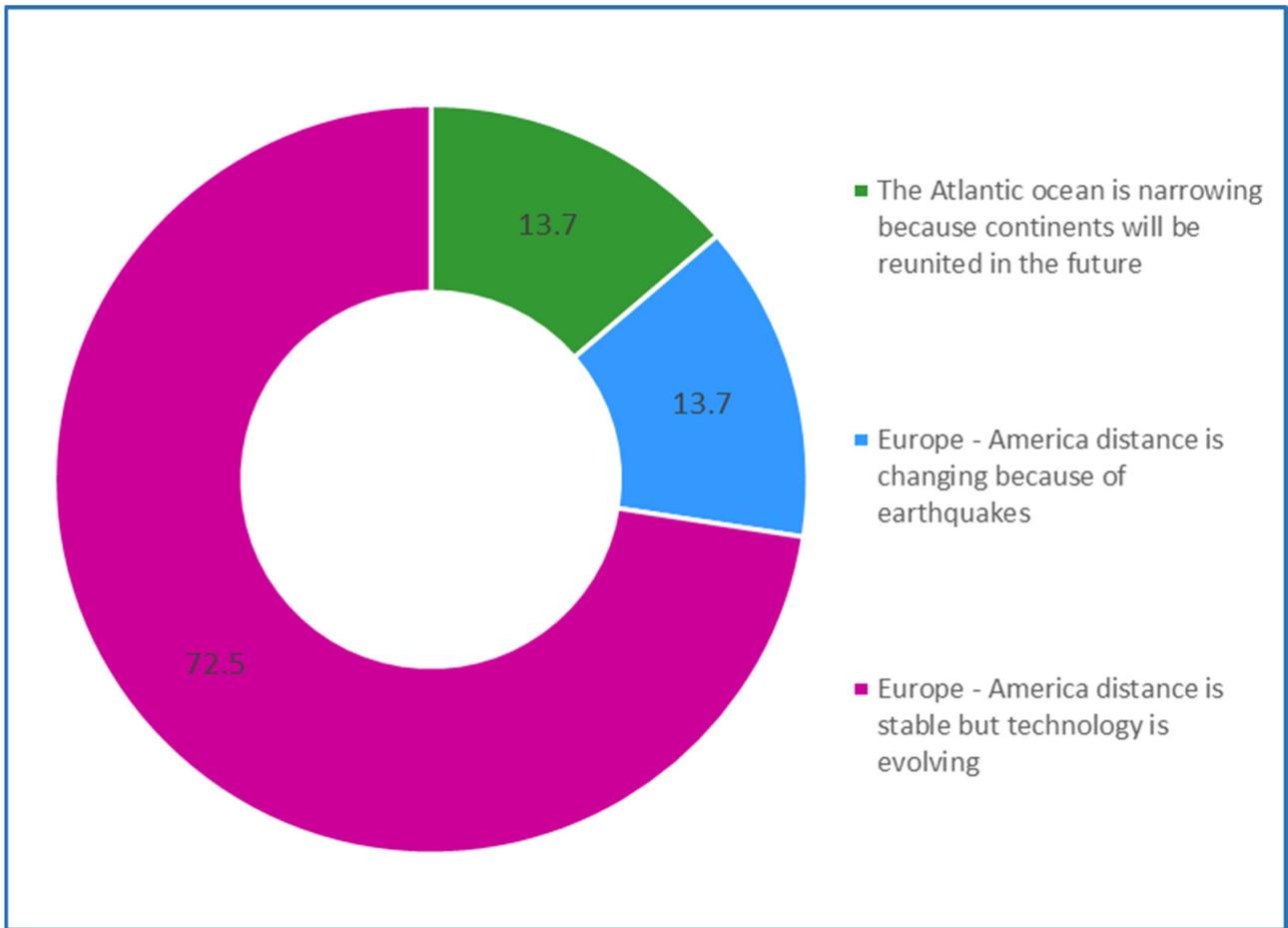


Figure 13. Students' alternative ideas on plate movement. (Answers to question 17 in Table 1).

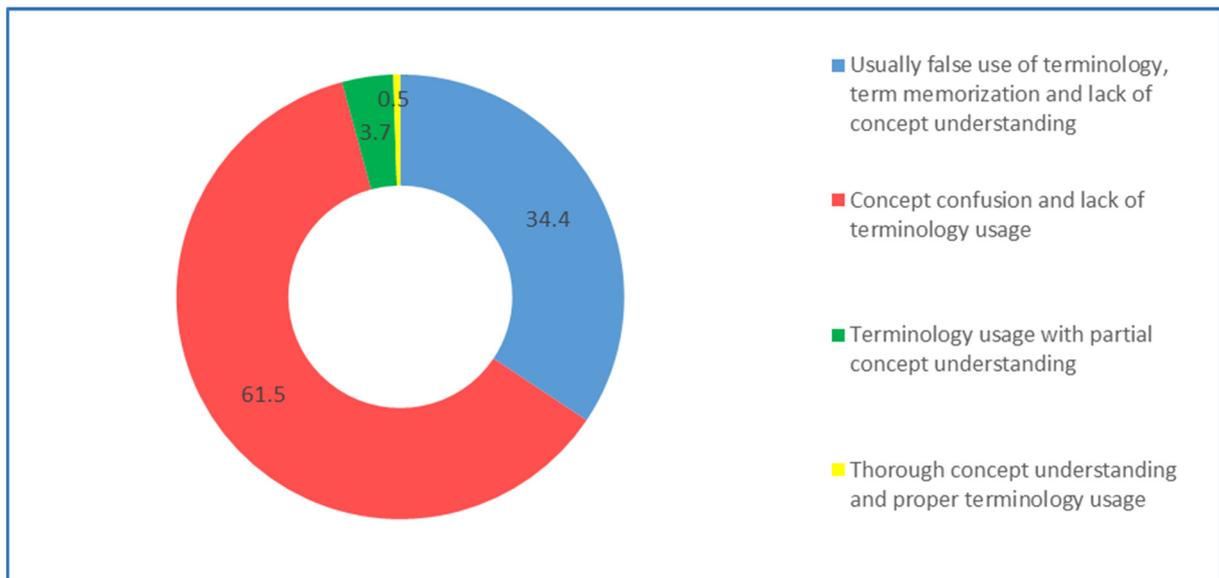


Figure 14. Terminology usage and concept comprehension by students.

5. Discussion and Conclusions

In this paper it is recorded that 12–13 year-old Greek students bear initial alternative ideas on geodynamic phenomena, which ideas are confirmed to be the results of interaction between students and their environment, as documented by Vosniadou and Brewer [47]. Furthermore, our data are in agreement with the concept construction model which presents that students are exposed to new incoming information which in turn is incorporated into their initial ideas giving birth to more complicated concepts named synthetic [47,48]. These synthetic ideas, if they are not the result of false concept textbook and teaching transmission, seem to be an intermediate stage before scientific knowledge achievement showing the progression of knowledge acquisition [30].

The students' new synthetic alternative ideas on geodynamic phenomena that come out from this study are introduced below:

- i. The Earth surface is horizontal and under it lies the spherical core.
- ii. Deep down in the Earth there are "plates" and only at the time they are colliding an earthquake can occur (instantaneous event).
- iii. Relief change is attributed to pollution, technology, vegetation, and generally human intervention.
- iv. The Mediterranean Sea will expand in the future (in terms of relief change attributed to ice melting and to subsequent sea level uplift).
- v. Mountains can occur in the future only under the condition that plates move again (students express instantaneous and not continuous procedure).
- vi. The Atlantic Ocean is becoming narrower because the continents will reunite in the future. So, North America and Europe continents come closer.
- vii. The tectonic plates can move and trigger earthquakes even if the Earth's core is empty or cold.

A synthetic alternative idea that constitutes an integrated mental structure and which students use to satisfactorily interpret a phenomenon is called a synthetic mental model [47]. One such model on geodynamic phenomena that arises from this research presents that "Earthquakes occur only when plates deep down within Earth collide (instantaneous procedure). After collision, plates move away from each other and stop moving. After a while, plates start moving and come closer again, and when they collide again (instantaneous procedure), an earthquake (instantaneous event) occurs and so on. Aftershocks are the results of weaker collisions". This model proves students' misinterpretation on the duration and continuity of geodynamic phenomena.

We believe that the more research is conducted, the more additional concepts will emerge. So, we must redirect our goal to focus on (a) concept construction, (b) concept characteristics, (c) concept usage as a measure tool when implementing new teaching techniques or re-evaluating textbook, curriculum, student, and teacher concepts, which has been strongly indicated by our data and international research the last decades.

Summarizing the above qualitative and quantitative analysis and reviewing past research [22,30,47,50,63], we outline the characteristics of both initial and synthetic alternative ideas of students aged 12–13 years old on geodynamic phenomena as described below:

- i. Students create a conceptual basis from their interplay with the natural and artificial environment, on which new incoming information from media, school, internet, etc., is automatically amalgamated.
- ii. Students attribute geodynamic phenomena occurrence to each other simultaneously.
- iii. Students display difficulty in exploring for the cause of geodynamic phenomena, demonstrating deficiency in causal thinking.
- iv. Students are capable of describing the repeatability of the phenomena in the future.
- v. Students consider geodynamic phenomena as instantaneous events.
- vi. Students cannot perceive the continuity of geodynamic phenomena. Thus, they struggle to describe them as unceasing procedures, depicting inadequacy of continuous thinking.

- vii. Students exhibit serious constraints in process description, a lot more in process interaction management.
- viii. Students bear a cognitional gap as far as the correlation of surface phenomena and inner Earth is concerned.
- ix. Students in their conceptual frame locate geologic concepts, which they find arduous to apprehend and interpret (e.g., lithospheric plates), far away from the Earth surface and their living environment.

Furthermore, the correlation of the present findings with previous research (e.g., [5,7,15,16, 51–53]) allows us to verify some of the aforementioned factors that direct students' alternative ideas on geodynamic phenomena such as environmental ones (e.g., soil, water, horizontality, etc.), media, textbook, and curriculum errors, specialized scientific terminology usage, lack of observation of geodynamic procedures, consideration of learning as a procedure of term memorization, etc. We especially emphasize the insufficiency of causal and process thinking, as determinant actors of misconception generation. It is important to note that students' interaction with their environment seems to exert more powerful influence than simple information transmission in concept development.

In addition, this research comes up with more recommendations that enrich the aforementioned list. We believe that the factors that are summarized below also play a crucial role in the construction of 12–13 years old student alternative ideas, both initial and synthetic, about geodynamic phenomena. These factors are:

- i. lack of students' continuous thinking,
- ii. current affairs and contemporary daily issues, such as: pollution, abrupt technology evolution, rapid increase in environmental human intervention,
- iii. features of geodynamic phenomena such as: spatial distribution, temporal distribution, frequency and intensity during the time and at the place where students live (especially because of the impact on humans and infrastructure).

We strongly believe that the knowledge of how some of these alternative ideas on geodynamic phenomena are structured, the factors, that control their formation, along with the characteristics of both initial and synthetic ideas can provide scientists with more clues so as to illuminate how these concepts are generated. This knowledge can also constitute a baseline for every instruction on geodynamic phenomena. In this sense, every teacher should pay close attention to these factors and characteristics and take them into careful consideration during the designing and performing of teaching procedures so that students can achieve the highest scientific knowledge possible. Still, further research is compulsory to enhance our knowledge on conceptual development, which in turn will clarify the processes of alternative idea construction and deconstruction, knowledge construction, and learning progression, thus changing our way of thinking on knowledge acquisition and advancing geoscience education.

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