

**Continental drift:
A discussion strategy for secondary school**

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Continental Drift: A discussion strategy for secondary school

A DISCUSSION STRATEGY FOR SECONDARY SCHOOL

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Abstract. The paper describes a discussion strategy for secondary school students. The strategy focus the various dimensions of Science, especially the internal sociological and philosophical dimensions. Students are expected to learn more about Science, namely the role of controversy for scientific progress. The article contains key questions for the students and guidelines for the teacher and also an analysis of the strategy in terms of the construction of Science and of learning processes.

Key-words. discussion strategy; continents movement; science construction; pedagogical analysis.

Introduction

The goals for science education in Portugal are being revised in order to emphasize science construction and the STS relation (Ministério da Educação 2001). This follows international trends (BSCS 1995). In the past, the scientific education approach was often reducing, consisting on a neutral body of knowledge from which the metascientific concepts were absent. This perspective of science teaching kept apart the scientific data and conclusions from the conceptual structure that gives meaning to those conclusions. This may lead students to a wrong idea of the processes of science construction. This paper aims at proposing a strategy for science teaching which highlights these processes. The strategy constitutes a dynamic instrument that allows students to achieve knowledge through reflection and discussion rather than by just given information. On the other hand, it is important to make clear that the work presented is mostly directed to the activity of the teacher and constitutes an instrument that has the main goal of contributing to teacher's education. Furthermore, it is not only an instrument to use in classroom, but it also may act as a source of inspiration and a conduct line to follow – if the teacher has the intent to create something similar in his/her school practice, no matter the subject. When the teacher is in full control of this kind of activities, he/she may, and must, promote more open strategies in the classroom.

The strategy presented in this paper was constructed by four student-teachers within the discipline of Science Methods and reflects the application of scientific and pedagogical knowledge. The paper is organized in order to promote the construction of metascientific concepts related to the continental drift and the controversy it raised. Given the complexity of the scientific and metascientific knowledge involved, the strategy is directed to high school. The collaboration among student-teachers contributed to a deeper understanding and applying of the way science is built

which will have positive effects on their future teaching practice. Professional teachers can construct activities of this kind if they also manage to develop a relation of collaboration and a deep interest in the improvement of science education and if they have acquired the knowledge and competences to do that. Such knowledge and competences can be obtained in well-structured science methods disciplines at the initial training level, as in the present case, or in conditions of in service training. This evidently, raises the problem of good trainers/teachers. The disciplines of Science Methods attended by the four present student-teachers were characterised by very specific features, among them a strong intra-disciplinary relation between scientific and metascientific concepts along the whole course and a strong conceptual structure of all pedagogic and scientific contents and competences. They were also characterised by a pedagogic practice similar to the practice future students are expected to implement (Morais, 1995, 2000, 2002).

The strategy applies various principles. Concerning the construction of science, we followed Ziman (1984) according to whom it is possible to distinguish four dimensions of science construction: historical, philosophical, sociological and psychological. This strategy focus the three first dimensions. From the point of view of students' learning the strategy is based on social constructivism as developed by Vygotsky (1978) and on Bernstein's theory of pedagogic discourse (1990, 1996), particularly on its concepts of classification and framing (power and control relations in the classroom). Vygotsky's ideas gain a deeper dimension when Bernstein's internal language of description, developed by Morais and Neves (2001), is applied. Their research indicated a mixed pedagogy as favourable to learning, going beyond the dichotomies close/open school, visible/invisible pedagogies, reception learning/discovery learning. The strategy presented in this paper is somehow characterised by this kind of pedagogy, which has the potentiality to lead students to acquire recognition and realisation rules to produce the legitimate text. This strategy was constructed for the transmission context, i.e. the context where students have the opportunity to acquire knowledge and develop competences. The teacher should also develop ways of assessing that acquisition. Although it is clear to teachers how to assess scientific knowledge and competences, it is less clear how to assess the understanding of metascientific concepts. Nevertheless, if these concepts are to be learned they should be assessed. The teachers should do that by introducing specific questions in tests or by asking for any other kind of individual work.

The need for the reconceptualization of science education emerge from the deep transformations that occur in our societies, which establish a biunivocal relation with both technological advance and scientific knowledge – the Science, Technology and Society relation (Santos 1998). The present strategy focuses on some of these issues to make explicit that the science construction is a dynamic and open process, sometimes generator of many controversies and disagreements between scientists and, that the social acceptance of science is dependent on

social contexts and on ideologies. Controversy is a major feature of science construction, which usually allows science advance. Thus, the strategy gives special emphasis to the sociological and philosophical science dimensions, with some reference to the historical dimension. Students have the opportunity to learn and apply scientific concepts (e. g. the spreading of the oceans floor) and metascientific concepts (e. g. data interpretation; hypotheses formulation). They also have the opportunity to develop cognitive competences (e. g. critical and reflexive thought) and socio-affective competences (e. g. participation in discussions, recognition of science potentialities and limitations). It is important to point out that these competences will be developed in situations new to students. Within this context, some assumptions underly the strategy: it allows students to understand how to reach conclusions from data interpretation; that distinct forms of data interpretation change with knowledge advance; that because of these principles and conceptual alterations, knowledge changes also occur; and that when knowledge changes it is for 'good' reasons –more and better is known than before (BSCS 1970).

This strategy assumes that students have already learned some aspects of Wegener's continental drift hypothesis (7th year of schooling – ages 12-13) and that, when they studied the syllabus section "Plates Tectonic – An Unifying Model" (Ministério da Educação 1995, p.114), they learned the convection currents mechanism, the isostasy principle (Press & Siever 1998) and aspects of science construction (Ziman 1984). On the other hand, this strategy has a multidisciplinary character, since it presupposes knowledge acquired in Physics (Geophysics). This strategy should be included in the learning unity of plates tectonic. In order to provide discussion time to students, this strategy should be applied in two school classes. To facilitate the participation of all students and a proper guidance by the teacher, the classroom should have a 'U' table organization.

Finally, it is important to make clear that this is but one of the various strategies that should be developed to lead students to reach a good understanding of science construction. The present strategy should be regarded as a small part of the whole and as such containing partial ideas that are completed by past and future work in the science class.

The paper contains several data (regular font) and key questions (small caps) for students; directions for the teacher (small font); and an analysis of the pedagogical principles, which underly the strategy. The answers to questions should result from the discussion with students; answers given in teachers' guidelines should be viewed as suggestions. In order to structure the learning process, each part of the text and respective question(s) should be given in separate transparencies or in Power Point. The discussion of each question should not end before the teacher is sure that all students reached the objectives of that question.

Discussion Strategy

To the students:

In the last classes we recalled the Earth's internal structure, and we learned the existence of convection currents inside it. These currents are responsible for many phenomena that have occurred in the surface of the planet for millions of years. We also learned that the processes of science construction entail many dimensions: philosophical, psychological, sociological and historical (Ziman 1984).

We are now moving forward to study the evolution of ideas about the present position of continents and, through it, to deepen our understanding of science construction.

This introduction aims at leading students to understand that the strategy is focused on scientific and metascientific concepts.

To the students:

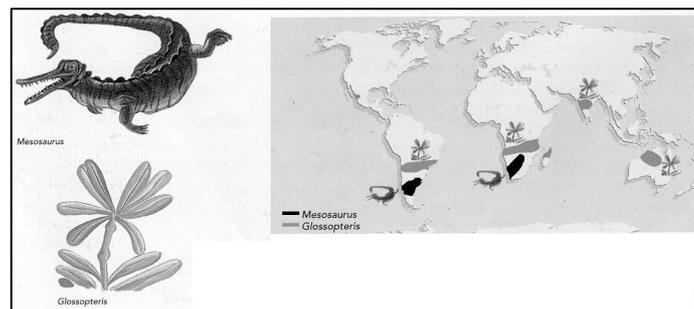


Figure 1. Geographic distribution of *Glossopteris* and *Mesosaurus* fossils with the same geologic age, inside each group (adapted from Motta & Viana 1998).

BASED ON FIGURE 1 WHAT PROBLEM CAN BE RAISED?

Students should define a problem like the following: Why are there fossils of the same genera and with the same geological age in so distant geographic places, as Africa and South America and Madagascar and India? By defining this problem, the students should recognize the philosophical dimension of science.

This question requires complex competences, entailed in problem definition.

To the students:

Consider the scientific problem defined in the previous question: "why are there fossils of the same genera and with the same geological age in so distant geographic places, as Africa and South America and Madagascar and India?" and observe Figures 2 and 3.

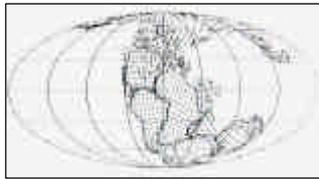


Figure 2. Continents configuration 200 millions of years ago (Origin: Young, 1986).

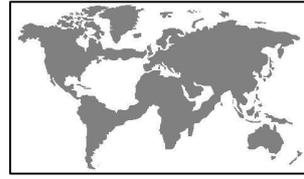


Figure 3. Continents configuration 200 millions of years ago.

STATE THE HYPOTHESIS THAT UNDERLY EACH ONE OF THE TWO DISTINCT CONTINENTS POSITION.

After the discussion of the students' ideas, the hypothesis, based on Figure 2, should be similar to the following one: many years ago the continents were joined together in a unique continental mass – Pangea – which made possible the presence of the same fossils in distant geographic places. Based on Figure 3, the hypothesis should be: many years ago there were continental bridges that linked some continents, as Africa and South America and Madagascar and India, which made possible plants and animals movement from one place to another. Once again, the students should recognize the philosophical dimension of science.

Suggestion: If students can not understand how plants moved from one place to another, the teacher can remind them that plants grow up from seeds and spores. These structures have the capacity to live in a latency state and can be transported by animals, wind, etc.

As in the previous question, complex cognitive competences are required because students have to define hypotheses and understand that one problem may lead to different hypotheses.

To the students:

The two hypotheses defined in the previous question were similar to the hypotheses proposed by scientists, about one century ago: (1) "many years ago the continents were joined together in a unique continental mass – Pangea – which made possible the presence of the same fossils in distant geographic places"; and (2) "many years ago there were continental bridges which linked some continents, as Africa and South America and Madagascar and India, that made possible plants and animals movement from one place to another". This shows how the same facts may lead to distinct hypotheses: the continental drift hypothesis (proposed by Wegener in 1912, cited in Hellman 1998) and the continental bridges hypothesis (proposed by Suess in 1904, cited in Oreskes 1999).

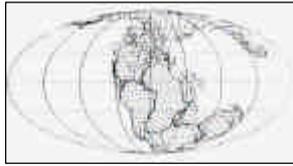


Figure 4. Pangea map
(Origin: Young, 1986).



Figure 6. Actual map
configuration.

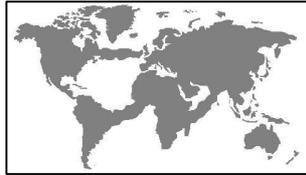


Figure 5. Illustrative map of
the continental bridges
hypothesis.

Consider that, in the present, there are no evidence of continental bridges and observe the Figures 4, 5 and 6 which show the transition from the former continents positions to the present position, according to each one of the two hypothesis.

WHAT MECHANISMS CAN YOU DEFINE FOR EACH TRANSITION?

HOW ARE THESE TWO THEORIES DIVERGING IN THE EXPLANATION OF THE CONTINENTS PRESENT POSITION?

The teacher must present the first question separately from the second. In the first question, and for the continental drift hypothesis, the students must refer that the continents separated. They can mention some of the explicative mechanisms for this separation, like continents buoyancy and the separation due to forces action (Holmes & Holmes 1980). For the continental bridges hypothesis, the students can refer that bridges disappeared by erosion and immersion mechanisms (Uyeda 1978).

The teacher should then confront the students with the second question. They will see that the divergence between the two theories lies on the way they explain the same phenomena.

The philosophical dimension of science is still focused in these questions.

The discussion requires the application of knowledge to new situations.

To the students:

The two theories that we examined gave rise to a confront of ideas in the scientific community. Knowing that in a given moment the continents position on the surface of the Earth

could be only one, the scientists had to find out which was the best theory to explain the reality. For that, they based themselves on geographical, stratigraphical and geophysical knowledges:

1. The continents outlines adjust like a puzzle, particularly when we analyse the coast lines in the Atlantic Ocean (Figure 7) (Uyeda 1978).

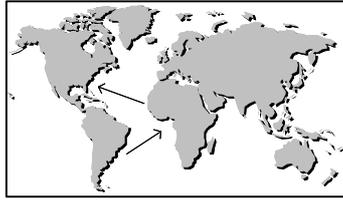


Figure 7. Illustrative scheme of the groove possibility of the coast lines through the Atlantic Ocean.

2. There are the same stratigraphic sequences in slope regions of continents geographically separated. The North America slope region has the same stratigraphic sequences found in Europe. The same situation is found in South America and Africa Atlantic coast and also in Madagascar and India coast (Figure 8) (Uyeda 1978).

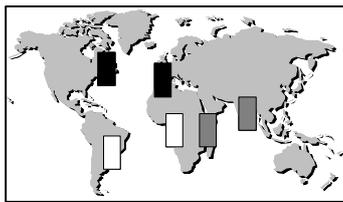


Figure 8. Illustrative scheme of the stratigraphic sequences in slope regions of the geographically separated continents.

3. The continental higher places have a thick crust, when compared with oceanic elevations, due to the difference of density (isostasy principle). So, the continents and oceans separation was a consequence of the structural and compositional difference of the interior of the Earth (Press & Siever 1998). In this way, a continent can not founder to give rise to a ocean or vice versa (Figure 9).

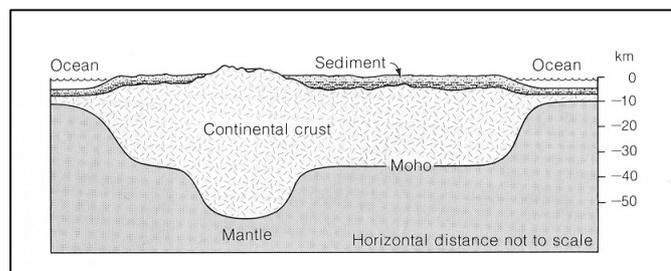


Figure 9. Illustrative figure of the isostasy principle (from: Press & Siever 1986).

BASED ON THIS NEW INFORMATION DISCUSS THE TWO HYPOTHESES YOU DEFINED.

On the basis of the second set of data provided, the students could refer that the existence of the same stratigraphic sequences in distant places correspond to the bridges insert zones. In this case, the teacher should refer that this data was a strong argument to the defenders of the continental bridges hypothesis. However, students should understand that this hypothesis was not supported by the third data, the isostasy principle, because even if bridges had been eroded there would be some evidence of its existence (Oreskes 1999). Furthermore, the adjusting that seems to exist between the continents outlines would be pure chance if this theory was accepted.

On the other hand, the continental drift hypothesis is supported by the other two evidences, because the adjustment of the continental outlines like a puzzle and the presence of the same stratigraphic sequences would point out to the idea that the continents were joined together in the past (Uyeda 1978).

The teacher should call students' attention for the main difference between the two hypotheses: the vertical movement of the continents in the continental bridges hypothesis and the horizontal movement of the continents in the continental drift hypothesis.

This analysis continues to focus the philosophical dimension of science, because it highlights the presence of two distinct theories to explain the same phenomena by the scientific community, and contains multidisciplinary perspectives. It also emphasizes the historical dimension, because it considers science evolution based on previous knowledge and experiences.

This question allows students to develop the capacity of taking grounded decisions.

To the students:

In the beginning of the 20th century, explanations and theories set out by scientists to understand geologic phenomena (like mountains formation) were given without the continents motion perception. For example, at that time, Dana (Flint & Skinner 1977) defended that some mountains, not associated with volcanism were formed by the subsidence of great quantities of sediments and the resulting lifting and deformation of the adjacent stratum – geosynclinal theory.

In 1915, five years after Wegener developed his hypothesis of continental drift, he presented it to the scientific community, in his book "The Origin of Continents and Oceans". With his hypothesis, this scientist, who was a meteorologist, invaded many other scientific areas (Hellman 1998).

In 1928, Chamberlin (cited in Hellman 1998), an American geologist, states the following: "If we accept Wegener's hypothesis we will have to forget all what we learned in the last 70 years and we will have to start from the beginning".

WHY DO YOU THINK THERE WAS THIS REACTION FROM THE SCIENTIFIC COMMUNITY TO WEGENER'S HYPOTHESIS?

The objective is that students understand that when presenting new hypotheses to the scientific community, scientists may face many problems. In this case, Wegener's hypothesis faced strong criticism. The controversy arised

for two reasons: first the nature of the hypothesis, which was in contradiction with the ideas of the time; second, Wegener's invasion of disciplinary areas, beyond meteorology, led other scientists to consider him as an intruder (Hellman 1998).

It is important that the teacher makes clear that the controversy between hypotheses may lead to more evidence and deeper understanding, which allows science advance. Nevertheless, science does not always depend on debate or conflict.

The example of the geosynclinals theory has the objective of showing how the non-acceptance of the continental drift hypothesis was not only ill will, but also that for the scientific community there were other hypotheses that seem to explain the phenomena and which made sense, according to the existent knowledge.

In this question, the students should recognize the internal sociological dimension of science because of the interaction between the scientists in the scientific community.

To the students:

The continental drift hypothesis proposed by Wegener was only based on the observation of the continents outlines, which, as we saw, seem to fit in one another like puzzle pieces. Wegener considered that if the continents had been jointed in the past, then the union zones should had the same stratigrafic sequences. Later on, when Wegener was searching for evidence to support his hypothesis, he came across a Palaeontology article, which discussed the hypothesis of Brazil having been joined to Africa in the past, where he learned that palaeontologists had found affinities in fossils of the two continents (Uyeda 1978).

Wegener knew that his hypothesis would be object of a large disagreement, as we saw before. Nevertheless, he decided to publish it, assuming before the scientific community that he could not explain the mechanism responsible for the movement and separation of the continents.

WHICH WAS THE PROCESS OF THE CONSTRUCTION OF SCIENCE THAT WAS FOLLOWED BY WEGENER?

The students should refer the Rationalism as the main process of science construction followed by Wegener (Kunh 1970; Popper, cited in Chalmers, 1982). In case that students show difficulties to enounce the right concept, they may start by referring the steps of Rationalism that are implicit in the text. By doing this, the teacher should then emphasize Wegener's Rationalism position, which starts from a theoretical model followed by the search of data that may support it. This position is opposite to another one – Empirism – that presupposes the gathering of data before the formulation of a theory (Freitas 1998).

This question highlights two dimensions of science construction: internal sociological and philosophical.

To the students:

In 1929 Wegener tried again to have his hypothesis accepted and for that he published it again, adding new data:

1. He referred the geological concordances between the west coast of Africa and the east coast of South America, noted by Alex du Toit (Gass, Smith & Wilson 1972).
2. He included the mechanism that Holmes (Holmes & Holmes 1980) had proposed for the continental drift, based on the existence of thermal convection currents in the superior mantle (Figure 10). This mechanism was presented in 1928 in a conference of the Geological Glasgow Society.

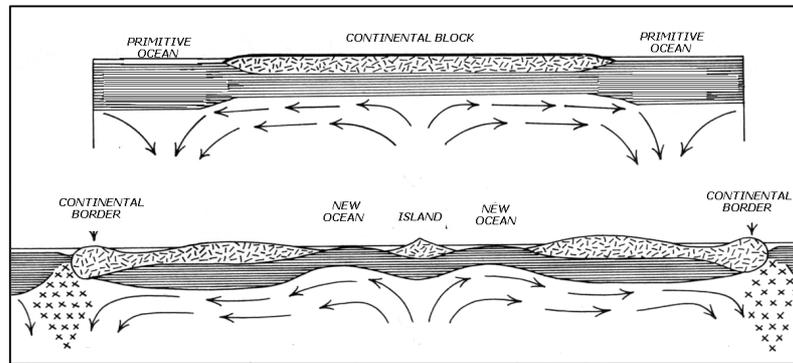


Figure 10. Diagram showing the convection currents mechanism proposed by Holmes in 1928 (adapted from Holmes & Holmes 1980).

IN SPITE OF WEGENER'S ADDITION OF NEW DATA, OTHER SCIENTISTS KEPT CONTESTING HIS HYPOTHESIS. DISCUSS POSSIBLE REASONS FOR THE PERMANENCE OF THE CONTROVERSY.

The purpose of this question is to lead students to remember knowledge learned before in this strategy or in previous classes. They have to interpret the figure and mention (1) the non-coherence between the isostasy principle and the mechanism presented by Holmes in 1928 – Holmes believed that when continents were separated by the action of the convection currents they would flutter on the oceanic crust; and (2) that this mechanism does not consider the existence, in the crust, either of locals with magma ascension (like it happens in rifts), or of locals where subduction of the oceanic crust under the continental crust occurs (Flint & Skinner 1977).

After the discussion, the students should refer that the mechanism proposed by Holmes in 1928 was different from the one accepted in the present (proposed in 1964). Initially, Holmes had imagined thermal convection currents in the terrestrial substrate (which today is named superior mantle). He was convinced that beneath the continents existed hot ascendant lateral currents that were responsible for the continents separation. On the other hand, in the locals where the continental convection currents gather the oceanic ones the submersion of both occurred. Later on with the separation of continents, the ascendant materials will have originated the ocean floors (Holmes & Holmes 1980).

In the course of the discussion, the teacher should tell students that these concepts were too advanced when compared with the ideas of the time, and also that technology was not as developed as today, making this mechanism of difficult understanding.

This question focuses the internal sociological and philosophical dimensions of science. This is also a question that focuses on student's previous scientific knowledge, requiring the development of complex capacities through the interpretation of the Figure 10.

To the students:

In 1939, nine years after Wegener died, the World War II starts, with consequences in many

distinct areas. With the war came the need of developing military defence and attack techniques. Consequently, there was considerable investment to develop technological tools previously invented (Uyeda 1978). Unfortunately, this contribution for science did not arise for its own sake, but with the intention of countries to become more powerful and prepared to war than others. However, after the war was finished, this technological progress allowed scientists to investigate the oceanic bottom. For example, the development of the acoustic magnetic precision register made possible the topographic cartography of the oceans floors (Uyeda 1978). The development of remote sensors also allowed the topographic cartography of the oceans floors, as well as the study of its rocks (Uyeda 1978).

IN WHICH WAY DO YOU THINK THE WORLD WAR II INFLUENCED SCIENTIFIC KNOWLEDGE?

Despite all devastating effects that the World War II had at several levels, the students must recognise that it allowed a huge technological development and its application on scientific investigation. Although many of the equipments had already been invented, they were rediscovered and improved.

This question addresses the influence of Society on Technology and on Science – the external sociological dimension of science is particularly focused.

Note: In case students are curious about Wegener's death, the teacher may explain that he died in a sledge pushed by dogs during an expedition to Greenland. There were very bad weather conditions (324°K under zero and 112Km/h of wind), to which Wegener could not resist (Young 1986).

To the students:

Without its principal defender, the continental drift hypothesis continued to be questioned, since there were no grounded proofs for the mechanism responsible for continents dislocation. This is, perhaps, the reason why Wegener's hypothesis was forgotten for almost 40 years.

With the technology developed during the World War II, scientists could study the oceans floors. Since the end of the 19th century it was suspected the existence of a crest on the Atlantic Ocean floor. Wegener had that knowledge, but he did not relate it to his hypothesis because he thought it was unimportant. However, the understanding of the volcanic origin of the crest with a deep valley in the centre (rift) from where comes out a strong heat flux (unknown until then), was only possible in the late 50's. Continuous investigations about the rift, led scientists to suspect that the heat flux had its origin in the mantle and that there were crests all over the oceans. It was observed too that rocks with more than 200 millions of years did not exist in the oceanic crust (Press & Siever 1998).

ON THE BASIS OF THIS NEW EVIDENCE, AND REMEMBERING EVERYTHING DISCUSSED SO FAR, WHAT IS THE CONTRIBUTION THAT THESE SCIENTIFIC ADVANCES MAY HAVE GIVEN TO THE

CONTINENTAL DRIFT HYPOTHESIS?

Since students had already learned the convection currents mechanism and the way rifts function, they should mention the ideas proposed by Hess (even if they do not identify the author) (Gass, Smith & Wilson 1972). Thus, the teacher should guide the discussion in order that students can enunciate the theory proposed by this author. Hess published his theory, named the theory of the seafloor spreading, in 1962. The postulates of this theory are that the mid ocean ridge gives origin to the new ocean crust. The oceanic bottom spreads for both sides of the crests and, probably, comes back down to the mantle in the subduction zones. The absorption of the oceanic crust in the trench zones constitutes a speculative idea, because it was never seen, but inferred on the basis that the earth is not getting bigger in volume and there is a preferential occurrence for earthquakes hypocenters in those places. Furthermore, there are only need of 200 millions of years for the oceans floors to be completely renovated. Thus, the oceans floors are not permanent, being in constant formation and destruction processes.

The teacher has a determinant role in leading students to understand the interconnection between the theory of the seafloor spreading and the continental drift hypothesis proposed by Wegener. Thus, it is important that the teacher gives emphasis to Hess's theory, which made possible an explanation for the mechanism of the continents drift. This new data made possible the improvement of the Wegener's ideas.

This question addresses, once again, the philosophical dimension of science. The historical dimension of science is also present – it is evident the relation between previous hypotheses and new data.

To the students:

Geomagnetic data of Oriental Pacific, published in geophysics studies, were possible by the use of some specific equipment (magnetometers) that was installed in oceanographic ships. Through that equipment, important results were obtained about the distribution of the different polarity magnetic bands on the sea floor (Uyeda 1978).

These studies have showed that most of the bands are cut out at some points and are separated from each other several kilometres up to 1000Km. These points are coincident with the fracture areas where the uplift of magma occurs (Press & Siever 1998).

DO YOU THINK THAT IT IS IMPORTANT TO PUBLISH SCIENTISTS' RESEARCH RESULTS? WHY?

The students should understand the importance of the publishing of scientific research results. Through that procedure science becomes public and results may be used in scientific research. Furthermore, scientific publishing promotes the co-operation between scientists, which is essential to science development. The information provided might also promote the multidisciplinary that is inherent to science processes.

On the other hand, the teacher should discuss the fact that, in this case, the new data were important to support the theory of the seafloor spreading. In fact, these new data make evident the concept of the oceans floors movement and, by doing that, the Earth may be faced as a dynamic body. Old books and theories may have to be transformed, giving way to new scientific routes.

This question involves the historical, philosophical and internal sociological dimensions of science.

Note: The teacher may tell the students that, according to the theory of the seafloor spreading, the magma that rises from the hot mantle achieves the Curie point when it gets cold. At this moment the ironmagnesian minerals that constitute the new ocean crust magnetise in the direction (normal or inverse) of the magnetic field of a specific time. As the ocean floor goes slowly away from the middle oceanic ridge, it is inevitable that one band which was formed in a period of normal polarity becomes close to a band that magnetised in an inverse period, producing a band pattern (Moors & Twiss 1996).

To the students:

The theory of the seafloor spreading, formulated by Hess, in 1962 was supported by the evidence of the magnetic bands, and has contributed to the birth of a new and more clarifying theory to explain the continents movement: the theory of plate tectonics (Uyeda 1978).

On the basis of this theory many, new and eloquent data were obtained which, to a certain extent, accomplish the continental drift hypothesis. Nevertheless, only in the end of the 60's, after many technological advances, great discoveries and great conceptual changes, Wegener's hypothesis was best understood.

By that time, it became clear that even the name (continental drift) proposed by Wegener was not correct, because the continents did not move by themselves, but by their inclusion in the lithosphere plates. We now know that the lithosphere is divided in 12 main plates (Figure 11) which can move as a consequence of the physical properties of the material that lies beneath them – asthenosphere – which has characteristics of a solid that is partially fluid (Press & Siever 1998).

The continental movement proposed by Wegener appears as a consequence of the spreading and subduction of the oceans floor. This constitutes the explanation for the mechanism that so many 'headaches' caused to Wegener.

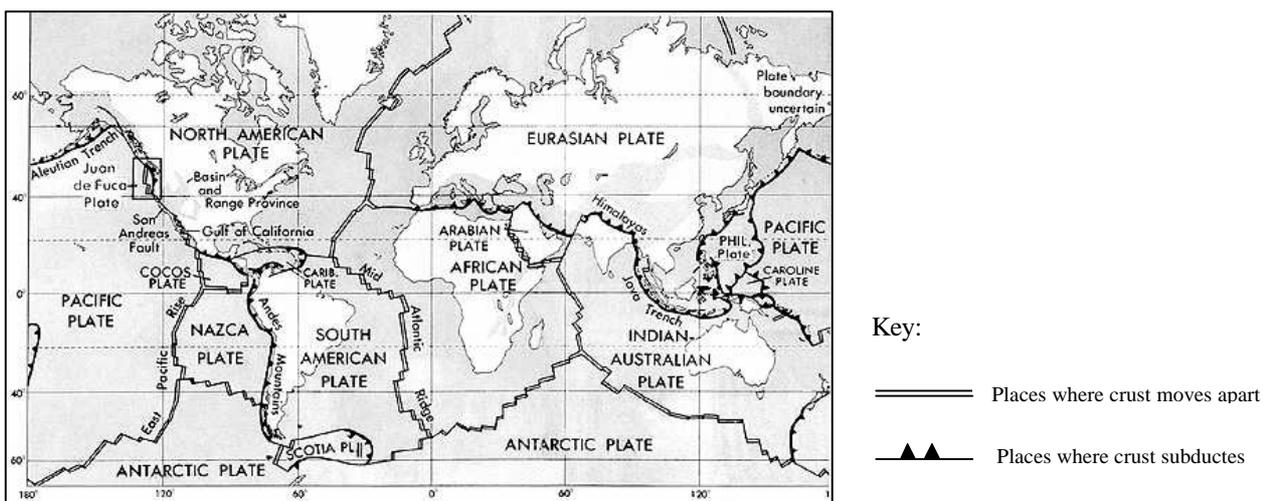


Figure 11. Lithosphere plates and their movements (From: U. S. Geological Survey).

BASED ON THE FIGURE AND REMINDING THE KNOWLEDGE YOU ALREADY HAVE, WHAT PREDICTIONS WOULD YOU MAKE ABOUT POSSIBLE CHANGES ON THE PRESENT EARTH MAP CONFIGURATION?

The teacher should guide students to find possible changes in the present earth map configuration, always paying attention to the knowledge learned during the strategy and in previous classes. The predictions can be similar to the following: (1) the Atlantic Ocean will continue to expand the opposite occurring with the Pacific Ocean; (2) the Mediterranean Sea will probably disappear, allowing the connection between Africa and Europe; and (3) India will continue to get close to the Asiatic Continent provoking an increasing in the altitude of the Himalayas. Who knows if in the next 220 millions of years transoceanic trips between America and Asia will not be needed?! As a curiosity, the teacher may tell the students that, even though the referred hypothesis is the most accepted, there is a portuguese geologist, António Ribeiro (cited in Mendonça 1995), who defends that a subduction on the occidental portuguese crust may have already started. As a consequence, it may happen that, in the next 200 millions of years the Marquês de Pombal statue passes over the Liberty statue!

In this question are present the philosophical and historical dimensions of science.

The interpretation of the figure requires from students complex competencies, simultaneously with the application of scientific knowledge.

To the students:

Rift and subduction zones are preferential places for the occurrence of earthquakes epicentres. It is now known that most of the earthquakes have had their epicentres in those places.

According to the *Expresso* newspaper of the 28th January of 1995 (Carvalho 1995), "during the last few years science has given to humanity the possibility to act against some dangers that our forefathers thought would never be overcome. The fact that the seismic risk may threat complete cities is a good reason for acting more vigorously [...]. The Japanese people [. . .] have mined their islands with sensors and other auscultation and registering instruments and they spend thousands of millions of yens in order to improve seismic studies and they have — for that reason — some of the greatest world specialists in this field".

KNOWING THAT PORTUGAL IS LOCATED IN A PLANET AREA THAT HAS SOME PROBABILITY OF SEISMIC OCCURRENCE, THINK ABOUT THE PREPARATION OF OUR COUNTRY TO FACE AN EARTHQUAKE SITUATION. COMPARE IT WITH YOUR KNOWLEDGE ABOUT JAPANESE CIVILISATION.

Firstly, the teacher should call students' attention for Japan's location in the junction of two lithosphere plates (Euro-Asiatic plate and Pacific plate) in the Fire Ring of Pacific (Young 1986), and to the fact that Portugal is located near to the frontier between the Euro-asiatic and the African plates, specifically at the Goring Bank, SW of S. Vicente Cape.

The students must use the information given and their own general culture about technological readiness of Japan, and should compare it with the Portuguese technological stage. It is expected that they refer, for example, that Portugal lacks well-built buildings concerning their preparation to seismic risks; there is a system, in Japan, which allows buildings and high structures to balance without falling. However, the teacher must tell students that Portugal has an adequate legislation concerning anti-seismic construction but, unfortunately, control on the buildings which are being built and maintenance of old buildings are lacking.

It should also be focused that awareness campaigns in the Portuguese society are missing (e. g. required procedures to adopt before, during and after an earthquake), and periodical rehearsals. This may be a consequence of a long period of time without significative earthquakes, whereas in Japan this is part of the population quotidian. The teacher should emphasize influence of Science on Society and on Technology (Santos 1998).

This reflection leads students to learn another aspect of external sociological dimension of science: its influence on Society. Furthermore, it is focused the importance of science on the development of new technologies, like the improvement of seismographs and civil construction techniques.

This question requires the application of knowledge to new situations.

Note: In order to lead to significative learning, this question should be adapted to the reality of the country where this strategy is applied.

To the students:

Alfred Wegener (cited in Waggoner 1996), on his book "Origin of Continents and Oceans" (1929) made the following statement:

"Scientists still do not appear to understand sufficiently that all earth sciences must contribute evidence toward unveiling the state of our planet in earlier times, and that the truth of the matter can only be reached by combing all this evidence. . . It is only by combing the information furnished by all the earth sciences that we can hope to determine 'truth' here, that is to say, to find the picture that sets out all the known facts in the best arrangement and that therefore has the highest degree of probability. Further, we have to be prepared always for the possibility that each new discovery, no matter what science furnishes it, may modify the conclusions we draw".

BASED ON THE PROCESS OF SCIENCE CONSTRUCTION, COMMENT WEGENER'S WORDS.

The aim is to lead students to relate previous knowledge in order to discuss some fundamental characteristics of science, namely its dynamic, continuous, multidisciplinary and questionable character. The students should understand that knowledge is a result of new information, that supports or refutes any given idea. Furthermore, it should be made clear that, even if the theory of plate tectonics is nowadays the most acceptable theory to explain the present continents position, this does not mean that it is correct, only that it is the one which offers more to explain the continental movement. That is why the research continues in many distinct areas to explain the new questions, which continuously arise.

In relation to that, it should be made clear that scientists should communicate between them in order to guarantee a great flux of information within the scientific community. This question is directed to the philosophical, internal sociological and historical dimensions of science.

Suggestion: Along the whole strategy, the teacher should promote a lively discussion over the whole issue and may write students' answers on the blackboard. A table (Table 1) may be constructed as the discussion progresses.

Table 1. *Metascientific knowledge related to the construction of science that was focused on the discussion strategy.*

Philosophical Dimension	Historical Dimension	Sociological Dimension	
		Internal	External
<i>Methodology (Investigation steps)</i>	<i>Science evolution</i>	<i>Relations inside the scientific community</i>	<i>Relations between science and society</i>
Perception that there is a problem; Definition of a problem; Formulation of hypotheses (perception that the same problem may give raise to more than one hypothesis); Understanding that the discovery of new data may transform the previous hypotheses; Perception that a theory can be formulated in a rationalist way; Understanding the importance of sharing information inside the scientific community; Perception that the scientific conclusions are not definitive and immutable.	The discovery of new data may lead to the interaction of theories that already exist; Importance of scientific publication.	The existence of different ideas to explain the same problem may lead to more evidence and deeper understanding; The scientific publication allows the cooperation between scientists and the development of research based on published information.	Despite the devastating effects World War II had, it promoted the development of already existent instruments, which led to new scientific investigations; The evolution of scientific thought concerning the mobility of continents led to a better knowledge about earthquakes and, consequently, the development of adequate technology to minimize their effects.

When the discussion is finished the students should reach a concept, which reflects the main idea that they should have reached and which is related to science controversy. This concept should be similar to the following: "The evolution of the scientific thought entails often a controversy between scientists that lead them to look for new evidence and to use new arguments, thus contributing for scientific advance".

Analysis of the Discussion Strategy

The analysis of the discussion strategy is focused on two major pedagogical principles: *the what* of learning (construction of science) and *the how* of learning (psychological and sociological perspectives). Concerning the construction of science, Ziman's principles (1984) were followed. The psychological learning process underlying the strategy is particularly based on Vygotsky's

theory of instruction (1978) and the sociological learning process is based on Bernstein's theory of pedagogic discourse (organisation and interaction in the classroom) (1990, 1996).

This analysis is specially directed to the teacher because it helps him/her to understand which are the pedagogical principles that underly the strategy and aids him/her to valorize some aspects that, otherwise, he/she would not do.

Nevertheless, the aim of this kind of analysis is to emphasize the importance of a pedagogical reflection of every work done, in order to analyse if the teacher's goals are met by the activity. It should be noticed that a pedagogical analysis of this kind is much more than merely background context, because it shows a reflection done by student-teachers (that should also be done by teachers in effective) that, undoubtedly, contributes for the significance of the teaching-learning process.

1. ANALYSIS OF THE STRATEGY FROM THE POINT OF VIEW OF SCIENCE CONSTRUCTION – THE WHAT OF LEARNING

According to Ziman (1984), science should be faced as a social institution and, for that reason, we should distinguish four metascientific dimensions of science construction: philosophical, psychological, historical and sociological (internal and external). These four dimensions are not independent of each other, their inter-relations should be considered. The philosophical dimension refers to the scientific investigation methodology; the psychological dimension of science construction refers to the scientists' personal characteristics; the historical dimension of science construction takes into consideration that science "evolves by a linked sequence of research publications" (Ziman 1984, p.8); the internal sociological dimension refers to the scientists' relations inside the scientific community; and the external sociological dimension refers to the biunivocal relation between Science and Society: Science influences the Society that surrounds it and "the inner workings of science itself are being changed out of all recognition by the enormous social forces acting on it, and penetrating to its philosophical and psychological core" (Ziman 1984, p.5).

Table 1 presents some examples of the metascientific knowledge focused on the discussion strategy.

Students must understand that science has several dimensions, in order to perceive science as a dynamic process that is *really* in construction and depends on many factors. Furthermore, the understanding of the various dimensions of science construction helps students to be open-minded towards the issues and problems.

2. ANALYSIS OF THE STRATEGY FROM THE POINT OF VIEW OF THE HOW OF LEARNING

Analysis from a sociological perspective

According to Bernstein (1990, 1996), the pedagogic practice used by teachers in the classroom is defined by specific power and control relations between subjects, spaces and discourses.

Power is defined by classification which indicates the degree of maintenance of boundaries between categories (subjects, spaces and discourses). Classification is strong when boundaries between categories are well marked and is weak when boundaries are blurred (Domingos et al. 1986). Control is defined by framing and refers to the communicative outcomes of the social relations between categories. Framing is strong when higher categories (e. g. the teacher) have the control of the social relation and is weak when lower categories (e. g. the student) have some control of the relation.

Table 2 presents the analysis of the strategy from this sociological perspective. Analysis of the classification considered the boundaries between the categories subjects (teacher – student and student – student), spaces (teacher – student space and student – student space) and discourses (between disciplines, within a discipline and between academic and non-academic discourses). Framing between subjects (discursive rules and hierarchical rules) and between academic – non-academic discourses were also considered.

According to Morais and Neves (2001), a mixed pedagogy of weak and strong classifications and framings according to specific aspects of the pedagogic practice is more favourable to *all* students' learning. The characteristics of the practice followed in the strategy are presented in Table 2. They follow mostly what those authors have found in their research. However, it should be noticed that framing of selection and sequence should be weakened in later learnings, when the students have already acquired the recognition and realization rules for science classes.

Table 2. *Analysis based on Bernstein's theory of pedagogic discourse*

INTERNAL CLASSIFICATION	INTERNAL FRAMING
<i>SPACES</i>	
<p><i>Teacher-student</i>: weak classification. For a dynamic discussion, teacher should walk around the classroom. This classification is somehow strong because students do not have direct access to the strategy material.</p> <p><i>Student-student</i>: weak classification. Students' tables should be placed in 'U' to weaken the boundary between spaces. Nevertheless, this classification is still strong, because students are not working in groups and they do not share any materials.</p>	

<i>SUBJECTS</i>	
<p><i>Teacher-student</i>: strong classification. Teacher distinguishes from students, because he determines the pedagogic practice.</p> <p><i>Student-student</i>: weak classification. Discussion permits that all students can intervene, and teacher should value all interventions.</p>	<p><i>Teacher-student</i>: this relation is defined by discursive and hierarchical rules.</p> <p><i>Discursive Rules</i> <i>Selection</i>: strong framing. The teacher selects the scientific and metascientific subjects and also the type of strategy.</p> <p><i>Sequence</i>: strong framing. All presented material follows a sequence defined by the teacher where students can not intervene. At the micro-level framing is weaker, because students have some control on the sequence of the opinions they give.</p> <p><i>Pacing</i>: weak framing. The teacher establishes the time allocated to the strategy (two classes) but students' pacing of learning is, to a certain extent, controlled by the students, as the discussion progresses. The activity may even have to continue in a following class.</p> <p><i>Evaluation criteria</i>: strong framing. Students are guided to produce the legitimate text – evaluation criteria are made explicit.</p> <p><i>Hierarchical Rules</i>: weak framing. Students can intervene, give their opinions and assume distinct postures along the discussion.</p>
<i>DISCOURSES</i>	
<p><i>Inter-disciplinary</i>: strong classification. As a Geology lesson this field has more status than others, although somehow weakened by the introduction of contents of other areas.</p> <p><i>Intra-disciplinary</i>: weak classification. In this strategy, knowledges within Geology are interlinked, all having the same status with no boundaries between them.</p> <p><i>Academic -non-academic</i>: strong classification. Academic knowledge has higher status than non-academic knowledge.</p>	<p><i>Academic-non-academic</i>: weak framing. Some knowledge exterior to the school is accepted during the discussion, namely in the question where students have the opportunity to tell of their knowledge about earthquakes prevention techniques in Japan and Portugal.</p>

Analysis from a psychological perspective

Vygotsky's theory (1978) admits that social interaction is the basis of high mental functions (complex cognitive competencies). It states that cultural development begins at the social level, and

only after that, at the individual psychological level (Pires 2001). The teacher is, basically, a learning orientative who should give students a qualified amount of resources carefully selected, in order to promote the development of students' cognitive level. Vygotsky's psychological theory of development presupposes the existence of a proximal development zone, which means that there is a difference between the actual and the potential development levels (Pires 2001) (Table 3).

Table 3. *Analysis based on Vygotsky's psychological theory of instruction.*

Social Interaction.	The type of enlarged discussion, which is the basis of this strategy, promotes a social interaction between both students themselves and students and teacher. It is intended that students exchange their opinions and argue, explaining their point of view. This may be possible if the students are placed in 'U'.
Evidence of the Proximal Zone.	When students discuss among them and with the teacher, they listen to others' opinions and "think in group". This allows students to move up from their actual stage of development towards the potential stage of development of the whole group.

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