Third Misconceptions Seminar Proceedings (1993)

Paper Title: **DIAGNOSIS OF ALTERNATIVE CONCEPTIONS IN SCIENCE IN SPANISH PRIMARY SCHOOL STUDENTS**

Author: González, Fermín Mª.

Abstract: We are living at a crucial moment in the field of education in Spain. The accelerated pace of current life and the adaptation to technological, social, economical, political changes, call for new services from educative settings. Innovative actions which affect the "common places" of education are necessary (SHWAB, 1973; NOVAK, 1989).

With the 1991/1992 academic year a gradual process of reform of education in Spain has been initiated, related to both primary and secondary school levels. The theoretical basis of the reform are contained in the so called "white book". The psycho pedagogical principles and the contents corresponding to the different areas of the curriculum are detailed in the book which, also, emphasises "meaningful learning".

Keywords: Theories,Concept Formation,Educational Methods,Educational Theories,Concept Teaching,Misconceptions,Concept Mapping,Curriculum Design,Instructional Design
General School Subject: Earth Science
Specific School Subject: Geology
Students: elementary, undergraduate

Macintosh File Name: Gonzalez - Diagnosis
Release Date: 5-18-1994 G, 11-8-1994 I

Publisher: Misconceptions Trust
Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

DIAGNOSIS OF ALTERNATIVE CONCEPTIONS IN SCIENCE IN SPANISH PRIMARY SCHOOL STUDENTS

Fermín Mª. González
Professor E.U. of Didactics of Experimental Sciences
Public University of Navarra. Spain

What is required is a growing commitment on the part of those peoples who now enjoy plenty to help those who have so little. But this kind of altruism cannot be built on an education that is inherently fraudulent, designed for grades or test scores even when this attainment does not confer empowerment of the student. If we want moral citizens we must provide them with education that is inherently moral.
It has been said that there is nothing so unstoppable as an idea whose time has come. Let us hope and work together to beat swords into plowshares and also to use resources to improve the quality of education.

JOSEPH D. NOVAK, 1989

INTRODUCTION

We are living at a crucial moment in the field of education in Spain. The accelerated pace of current life and the adaptation to technological, social, economical, political changes, call for new services from educative settings. Innovative actions which affect the "common places" of education are necessary (SHWAB, 1973; NOVAK, 1989).

With the 1991/1992 academic year a gradual process of reform of education in Spain has been initiated, related to both primary and secondary school levels. The theoretical basis of the reform are contained in the so called "white book". The psycho pedagogical principles and the contents corresponding to the different areas of the curriculum are detailed in the book which, also, emphasises "meaningful learning".

Trough my intense professional activity (classes, lectures, seminars, etc.), I have been able to check the frustration that most of the teachers feel, due to the lack of both adequate guidelines and practical resources that empower them to successfully implement educative reform in the reality of school settings.

It is our opinion that theoretical ideas stemming from AUSUBEL (Assimilation Theory of Learning, 1968), GOWIN (Educating Theory, 1981) and NOVAK (Theory of Education, 1982), can contribute to solving the problem. An important empirical validation in educative systems of different countries and our own experience (GONZALEZ 1990, 1992; GONZALEZ Y NOVAK, 1993), allow us to trust such theoretical models.

The key concept of educative reform is meaningful learning. Related to that we have to take into account that meaningful learning has very important didactical/pedagogical implications that affect curriculum and instructional design. As a consequence of that, different materials must be conceptually reorganised, it is, also, necessary to develop positive attitudes in the learners regarding this type of learning and, finally, knowing the prior knowledge of students, so that, based on it, design either curriculum material or appropriate instructional strategies.

In the work we present, we will refer especially to the knowledge of the students' prior knowledge. We agree with AUSUBEL when he states that the factor which influences the most in future learning is what the learner already knows.

Current epistemological ideas consider that explanation is a human construction (NOVAK, 1988) and, also that explanatory models evolve with time. As a consequence new ideas are constructed and added. It is in this new conceptual and methodological scope that creative and meaningful construction of knowledge by students and the genesis of authentical and profound scientific attitudes are enhanced.

THEORETICAL BACKGROUND

Analysis of investigations of knowledge that students already have corroborates NOVAK's idea that there is a great potential for learning in human beings that remains undeveloped and that many educational practices dull instead of facilitating the expression of this potential.

NOVAK (1987) states that both instruction and evaluation model more frequently applied in schools and universities justifies and rewards rote learning and, often, penalises meaningful learning.

Current knowledge about human learning (metalearning) and processes by which human beings construct new knowledge (metaknowledge), can help to free much more intellectual potential of the students.

Investigations made at Cornell University, directed in school settings, from primary education to learning in adults, have strongly contributed to these advances. These investigational programs resulted in the development of a comprehensive theory of education (NOVAK and GOWIN, 1988). The implementation of this theory has led to the development of new strategies for teachers (and parents/tutors), to help students to learn how to learn. These learning teaching strategies are called "concept mapping" and "Knowledge vee" mapping.

The principle of meaningful learning includes the idea that each one of us has got only one sequence of learning experiences and consequently, acquires idiosyncratic meanings for concepts. In some cases, this idiosyncratic meaning separates from meaning culturally accepted and we say that this person has got a misconception or an alternative framework. After establishing these subsumer concepts in the cognitive structure, they are not easily modified (HELM and NOVAK, 1983).

The enormous number of possible permutations of both concepts and propositions justifies the idiosyncratic character of individual conceptual structures, although, in spite of this, there is sufficient common meaning for communication to be possible, and these meanings can be modified. This makes education possible.

In most school programs, it is frequent for students to learn by rote either definitions or procedures without relating their meanings with the ideas that they already understand.

We agree with NOVAK when he says that students reach the belief that memorising of school information is the only way of learning. Experience shows that, in many cases, we find ourselves powerless to diminish rote learning and increase meaningful learning. Two important reasons explains the difficulty of the problem.

1. The student is not aware that there is an alternative to rote learning.

2. The concepts to be learnt are presented in such a way that enhance memorising.

WANDERSEE, MINTZES and NOVAK (1993) in their extraordinary work about the current state of investigation on alternative conceptions in science draw eight knowledge claims from the analysed studies that have been published during the last twenty years in science education literature.

One knowledge claim states that students go to formal instruction in sciences, with a diverse set of alternative conceptions which have their origin in a diverse set of personal experiences and that they are both tenacious and resistant to extinction by means of conventional strategies of teaching. The prior knowledge of students interacts with knowledge presented in formal instruction, giving rise to a set of unintended learning outcomes.

It is necessary to know students' ideas, and to take them into account in the design of both curriculum and instruction so that meaningful learning by students can be enhanced. Only this way, we will be capable of promoting an adequate conceptual change and, by sharing meanings, have the ideas of students come closer to those of scientists.

NOVAK's concept maps and GOWIN's V diagrams help us identify, understand and organise concepts we plan to teach. They help us to specify necessary propositions for understanding. Concept maps and V diagrams made by students are effective ways of knowing what they already know. They facilitate the necessary interchange between teacher and student, revealing which concepts are in teaching material and in the cognitive structure of students.

Concept maps and V diagrams help students to understand the existing scientific knowledge and, also, help them to relate new concepts with those that they already have. As we think with concepts, this representation of the cognitive structures of the students allows the teacher to design educative events related with what students understand.

When students are capable of relating concepts of these new and old events, meaningful learning is taking place. Teachers and students can supervise together concept maps and V diagrams and discuss meanings expressed by them. Thus, concept maps and V diagrams are transformed into instruments for exploring and negotiating meanings.

Sharing the meaning of knowledge with the student, empowers the student to make decisions. We learn by adding new concepts to existing cognitive structure and which, in this way, is modified with time. As new learning is produced, it becomes strengthened because it is incorporated into an existing system.

DEVELOPMENT OF THE INVESTIGATION

The purpose of our investigation was to test alternative conceptions of our students regarding a natural sciences topic that was, on the one hand, familiar to then and, on the other hand, that had a curricular treatment in different levels of primary education.

The chosen topic which complies with both these requirements was: *Water in Nature*.

We were also worried about checking persistence and tenacity of alternative conceptions through different levels of Spanish primary education (levels 1-8)

For developing the work we contacted a group of teachers from the Public School "Jose María Huarte" of Pamplona (Spain), who give classes in levels two (7 years, 14 students), three (8 years, 17 students), five (10 years, 16 students) and eight (13 years, 20 students).

For obtaining pertinent information, instruments and strategies adapted to real characteristics of each class were used, taking into account the suggestions from corresponding teachers.

In the level two class a brain storming session was carried out, which was directed by the teacher on the basis of a series of basic knowledge, related with the topic. The session was recorded and students' oral interventions were transcribed.

After corresponding results were obtained, these, in addition to other information, were taken into account in time to elaborate a more complete and formalised questionnaire to be filled in writing by students belonging to superior levels (3-5 and 8).

In levels 3 and 5, the same methodology was followed, that is one brain storming session directed by respective teachers regarding basic knowledge of the topic. Sessions were recorded and the whole of the information transcribed. One variation was introduced in order to obtain one more complete piece of information about prior knowledge, and this information came from each of the students. Students were given a questionnaire, which among other basic knowledge, called for the opinion from the students regarding alternative conceptions detected in students belonging to level two.

For getting information about prior knowledge of students corresponding to level eight, as they already had some experience in elaborating concept maps, students at this level were supplied with a list of key concepts in relation with the topic and, also, were asked to elaborate corresponding concept maps. Besides this, and for obtaining more complete information students were given the same questionnaire as had been given to the lower level classes (i. e. level 3 & 5)

Finally, it was our purpose, to check the persistency of acquired knowledge by students, as an indicator of the type of learning experienced by the students and everything inside the university scope. For this, an investigation was made and a group of students belonging to the second course of sciences in the Teachers Training School took part in it. This group were trained in concept mapping techniques in the subject matter of Geology and after being instructed, students were asked to elaborate one concept map (February 2nd, 1991). One example of a map elaborated by a student appears in Figure 3. The concept map was related with the topic of Silicates, and was constructed using the list of concepts in Figure 1. Students were not given any prior information about the topic, although students should have got a theoretical background related to it as this topic is treated in levels 1 and 3 of secondary school (subject matter: Natural Sciences) and, also, some students studied this topic in a Geology program corresponding to the course called COU (university orientation course), necessary to gain admittance to University.

Figure 2 shows the concept map elaborated by the teacher on the basis of the list of relevant concepts for the topic of Silicates.

This group, after doing this, followed the course as usual with a conventional or traditional methodology, that is without using metacognitive strategies. The same group in the following year (academic course 1991-1992), studied the subject matter called Didactics of Experimental Sciences corresponding to the third course of Sciences. In this course students became familiar with concept mapping and V diagrams techniques that were used by students in order to design curriculum and instructional material to be used in Primary School. In the different units prepared by students which embraced, mainly, Chemistry, Physics and Biology topics, there wasn't anything related with Silicates.

At the end of the course (June 17th, 1992) and without any advance warning or opportunity to revise, the students were given the same list of concepts about Silicates as in the previous year and were asked to elaborate a conceptual map on the basis of that list used in the diagnosis of prior knowledge of students regarding the topic of Silicates of Geology in the second course.

Figure 4 shows the concept map elaborated by the same student who had done the concept map of Figure 3.

We have chosen concept maps elaborated by the student G.A., because, on the one hand, they are good examples of the general tendency of the group in the sense of the existence of numerous misconceptions in all the maps made, and also, because on the other hand, G.A. is a student who got good Grades in Geology in all partial examinations and a final Grade of 8.5 out of 10.

RESULTS

ALTERNATIVE CONCEPTIONS ELICITED FROM STUDENTS (14) BELONGING TO LEVEL TWO (7 YEARS) FROM THE SPANISH EDUCATIONAL SYSTEM

- For some students: "Evaporation is considered as a loss of water (there is not a clear idea of conservation of mass)
- Quite widespread is the idea that: "Water vapour raises towards the clouds (not forming these)
- Someone points out that: "Water burns when boiled"
- Some students consider that: "Water, when boiling, throws gas (which is inside the water), and it is released by heating"
- Often: "Water vapour is identified with smoke"
- Someone: "Uses the concept of stone to refer to pieces of ice"
- Some students: "Consider water, water vapour and ice as different things, there is not a clear idea of transformation or change of state"
- For some students: "Water vapour is kept in the clouds, it does not form rainwater".
- Someone: "Identifies snow with ice"
- Also quite widespread is the idea that: "Water vapour holds water and then drops it (when it rains). There is not a clear idea of transformation".
- Some students: "Believe that ice in nature (in the mountains) has the shape of ice cubes (According to the fridge model)".

ALTERNATIVE CONCEPTIONS ELICITED FROM STUDENTS (17) BELONGING TO LEVEL THREE (8 YEARS) FROM THE SPANISH EDUCATIONAL SYSTEM

(between brackets the number of students, if more than one, who think that way)

- A cloud does not fall because it is constituted by water vapour which weighs little and floats in the air (4)
- A cloud does not fall to the ground because it is held by the sky.
- A cloud does not fall because it is vapour which rises.
- Clouds do not fall to the ground because they fly.

- Clouds do not fall to the ground, because, if they did it would never rain.
- Clouds are constituted by water vapour (9)
- Ice in the mountains is formed by or can form little cubes (5)
- Water that is evaporated is completely lost (6)
- When water is boiled, it burns (7)
- When water is heated, the gas which is inside the water is released into the atmosphere (9)
- I would call a piece of ice "stone" because it is very hard (4)
- I would use the concept of stone to refer to a piece of ice, because when hail falls it seems to fall like stones.
- Water, water vapour and ice are different things (2)
- Snow and ice are the same (7)
- Water vapour forms drops of rain, when it is cooled (7)
- Water vapour holds water in the clouds and then it releases the water to form rain (6)
- Water is lost in evaporation, but "not everything"
- Water vapour rises to where clouds are but it does not form them (2)
- Rain is formed when water vapour is cooled in the clouds (3)
- Water vapour and smoke are the same thing: both are gas and, also, invisible (2)
- Water vapour forms the clouds and then drops of water
- Water vapour forms the clouds and then, if sufficiently cold, drops of rain.
- When water vapour is heated, it rises and enters into the cloud thereby forming water.
- The total content of water is evaporated because it is formed by gas.
- In evaporating water not all water is lost because little drops of water which can hardly be seen, are left.
- Water vapour rises towards the clouds and when these are completely full of vapour, the remainder of the vapour falls down in the form of water.
- Water vapour forms the drops of rain and does not stay forming the cloud.
- Snow is formed when water vapour in the cloud passes to a frozen state, when the air is very cold.

ALTERNATIVE CONCEPTIONS ELICITED FROM STUDENTS (16) BELONGING TO LEVEL (10 YEARS) OF THE SPANISH EDUCATIONAL SYSTEM

(between brackets the number of students, it more than one, who think that way).

- A cloud does not fall because the little drops in gas state that form the clouds do not weigh sufficiently to fall.
- The weight of drops of water in clouds is not sufficient so that it can fall to the ground (6).
- A cloud does not fall because it is formed by water vapour and it has little weight (4)
- Clouds do not fall to the ground because they do not have enough weight (3)
- Clouds are formed by vapour (8)
- Clouds are little drops of water that when they weigh sufficiently they fall down but not the cloud.
- Water is evaporated and it is turned into little drops which are in gas state.
- The little drops of vapour rise to the clouds in gas state.
- The drops of vapour rise to the clouds and with sufficient cold they become drops in liquid state.
- The vapour is transformed into little drops when it reaches cold clouds.
- Drops of rain form the clouds
- Water vapour forms drops of rain when it is cooled
- Vapour rises in the shape of little drops.
- Drops of water vapour when they are cooled in the clouds, form drops of rain.
- Vapour is formed by drops of water.(4)
- Vapour is cooled in the clouds and it is turned into little drops of water (2)
- Ice and snow are the same (7)
- Ice in nature is formed by snow
- Ice can form little cubes, although not always.
- Ice does not form little cubes because on the ground it melts.
- Ice by heating is dissolved.
- When water is heated sufficiently, the gas which is inside the water is released into the atmosphere (6)
- Snow is in the clouds and from there it falls to the ground as rain (2).

- Water is evaporated and it rises to the sky, where the air cools vapour water and drops of water are formed.
- Water is held by vapour in the clouds and, also, vapour produces rain.
- A part of vapour is left forming the clouds and another part falls to the ground as drops of rain.
- Vapour forms the clouds as it rains and the clouds are left.
- Wind pushes water downwards from clouds and it rains (2)
- Vapour forms the cloud but when it is cooled it falls and "it leaves it"
- Vapour does not form clouds because when vapour is cooled it forms drops of rain but the cloud stays there.
- Water is cooled, it rises to the atmosphere and then it falls.

ALTERNATIVE CONCEPTIONS ELICITED FROM STUDENTS (20) BELONGING TO LEVEL EIGHT (13 YEARS), FROM THE SPANISH EDUCATIONAL SYSTEM

(between brackets the number of students, if more than one, who think that way)

- As the cloud is vapour and this is less dense than air, the cloud floats (7)
- A cloud does not fall down because it contains water in the shape of gas (5)
- Only surface water is evaporated and it is lost, the remainder is left (3)
- Water burns because it is very hot
- Ice is snow in the process of turning into liquid water
- Snow is the same as ice (2)
- Snow falls from the clouds when the temperature is zero and ice falls when the temperature is much less (3)
- Snow does not melt, ice does
- Snow is ice in the process of thawing, that is when it is melted (2)
- Snow needs more cold than ice does, to form.
- Snow is hard or soft powder, and ice is frozen rain.
- Water is held by vapour in the clouds and then water is released to from rain (7)
- Water is in the clouds in the shape of gas and vapour holds it.
- Drops of gas join in nucleus to form clouds
- Clouds are constituted by vapour (15)
- Molecules of vapour form the clouds.
- The clouds are formed by gases (2)

- I would use the concept of stone to refer to ice because both are in a solid state (4)
- I would use the concept of stone to refer to ice, as it is as hard as stone (3)
- I would use the concept of stone to refer to a piece of ice, as water freezes better around stones.
- Ice is water which joined molecules, and it can have little cubes in its centre.
- It can be expected that there are little cubes of ice in nature but it is a little bit difficult (2)
- Ice will form little cubes depending on soil composition.
- Ice, in the mountains, melts quickly and due to this it can not be of one fixed shape.
- Ice can form little cubes, although they can be so small that we can not see them (2)
- Ice can form little cubes in nature, as molecules of the ice join little by little, in an ordered way, not suddenly (2)
- Vapour is not black and smoke is black.
- Smoke is a vapour.
- Smoke is a dirty vapour.
- The gas that water has inside it is released towards the atmosphere when water is heated to a sufficient degree (8)
- Streams of air press the clouds in such a way that clouds release water.
- Vapour water is ejected from the clouds and it forms rain
- When clouds are cooled rain is formed
- Water vapour is cooled in clouds and it causes rain (2)
- Water vapour is concentrated in the clouds and it can precipitate in the form of rain or snow.
- Water vapour, ice and water are different.
- Clouds are kept in the high in the sky when the temperature is, also, high, but if the temperature is low water vapour will be condensed and the cloud will fall down (2)
- Water vapour is the same as liquid water and drops of rain (4)
- Rain is formed because ice from the high parts of clouds falls and it is melted when passing through hot air streams.
- If the sky becomes cloudy and there is a little wind or cold, it rains.

DISCUSSION

- The data obtained confirm completely expectations posed in the investigation's work. On one hand in the sense of number, variety and frequency of alternative conceptions in the cognitive structures of the students and, on the other hand, about the persistence and tenacity of students' alternative conceptions.

There are a lot of curious explanations from the students about different phenomena and most of them are related to phenomenological aspects, fantasy, local or familiar context, personal experiences, the influence of mass media, etc. They all are pieces of evidence of the idiosyncratic character of individual knowledge.

From the point of view of misconceptions the most dramatic examples are, in our opinion, the following:

- Clouds are constituted by vapour water. This proposition has an enormous influence in the explanations of the students about the origin of rain, snow, dynamics in and of clouds, etc.

- When water is heated, the gas which is inside the water is released into the atmosphere.

- There is no clear idea about either conservation of mass or change of state (i.e. water that is evaporated is completely lost; water vapour and ice are identified as different things, etc.)

These misconceptions are, also, very good examples of the persistence and tenacity, as we find them in students from each one of the four levels of the primary school investigated.

The consideration of concept maps elaborated by students from the Training Teacher School in the first phase of the diagnosis of prior knowledge and the enormous number of misconceptions detected, indicate that rote learning has been dominant in most of them. This statement is, also, corroborated by the careful study of concept maps elaborated by the same students after a long period of time (more than one year). Concept maps elaborated by the student G.A. are the most dramatic examples.

In considering the second concept map of this student, I have to say that, although the instruction applied to the students was conventional or traditional, I am very disappointed due to the fact that there are no correct propositions which are meaningful corresponding to Tectosilicates after having emphasised the relations of this concept with other aspects such as, maximum sharing of oxygen atoms, great stability, plenty of feldspar and quartz in the fluvial deposit, etc.

Another surprising result is related to the concept of Phyllosilicates which in spite of having emphasised during instruction related aspects such as: etymology of the word, sheet structure anisotropy in some physical properties such as hardness and exfoliation, characteristics of clays and micas, etc.

CONCLUSIONS

The investigation allows us to draw some conclusions:

- Unfortunately misconceptions about scientific topics are very frequent in students of different levels of primary school.
- Misconceptions have proved to be both persistent and tenacious.
- Traditional or conventional instruction enhances rote learning, which is easily eroded.
- The complete lack of interest on the part of students to make an effort to relate new knowledge with what they already know can explain such bad results, even in cases of "good" students.
- This state of things about education in science obliges teachers to change habits, attitudes, methodology, etc.
- We need to reorganise conceptually both curriculum and instruction to promote meaningful learning.
- We need strategies of conceptual change to remove misconceptions from students because misconceptions influence negatively their future learning.
- An educational reform is urgent, but to do this it is absolutely necessary that teachers change their ways of thinking.

- Metacognitive strategies (concept maps and V diagrams) stemming from AUSUBEL-NOVAK-GOWIN theory are efficient resources to achieve the desired change.

1. QUARTZ	14. OXYGEN
2. SINGLE CHAIN	15. SHEET STRUCTURES
3. SOROSILICATES	16. TOURMALINE
4. MICAS	17. STRUCTURAL UNITS
5. TETRAHEDRA	18. THREE-DIMENSIONAL
6. INOSILICATES	19. PHYLLOSILICATES
7. AUGITE	20. TERRESTRIAL CRUST
8. SILICON	21. INDEPENDENT.
9. NESOSILICATES	22. ANNULAR STRUCTURES
10. OLIVINES	23. AMPHIBOLES
11. DOUBLE CHAIN	24. SILICATES
12. TECTOSILICATES	25. FIBROUS STRUCTURES
13. PYROXENES	26. HORNBLENDE

Fig. 1. List of concepts corresponding to concepts maps of Figures 2, 3 and 4

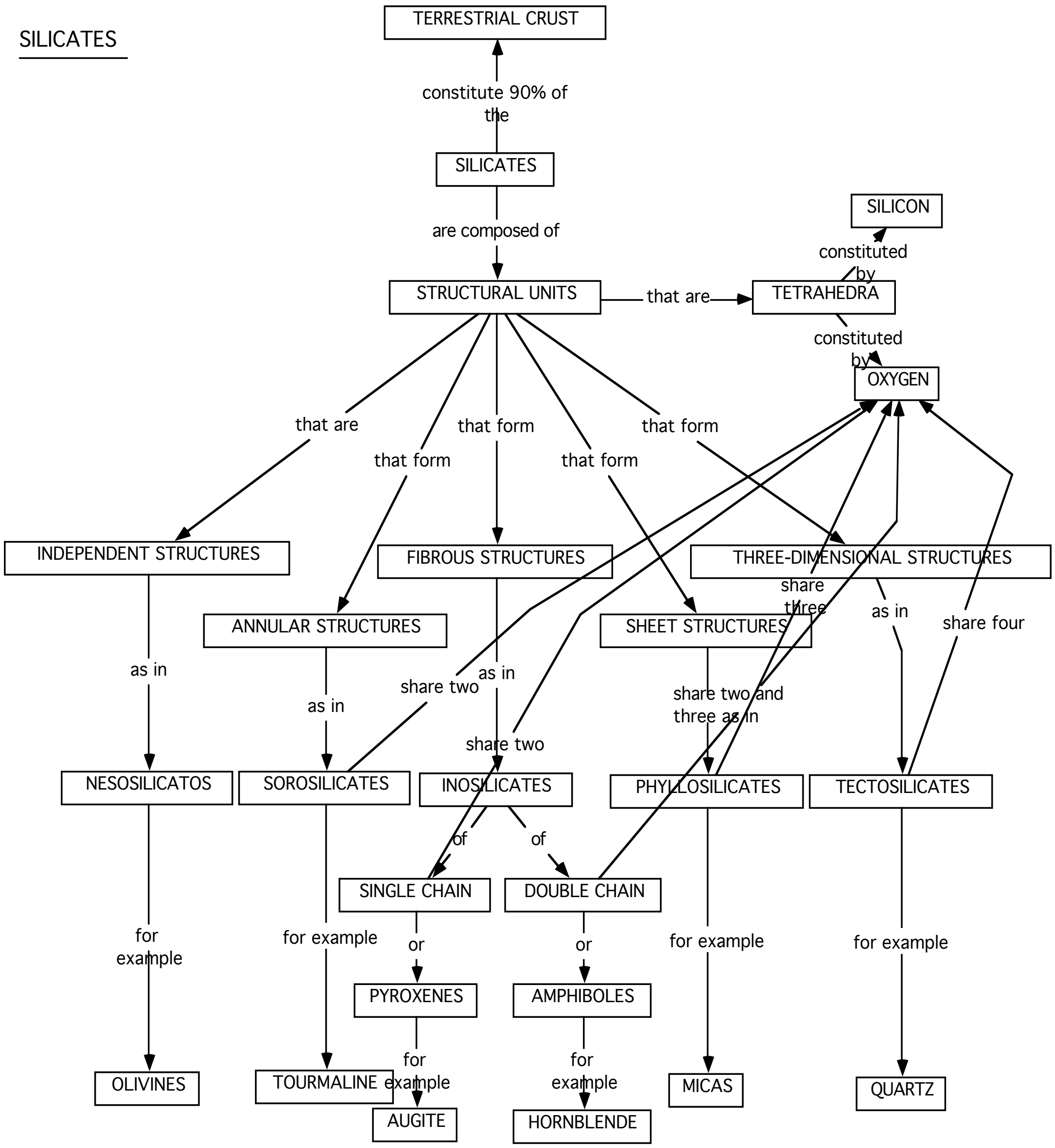

Fig.2. Concept map about relevant contents on silicates, belonging to geology program of second course of sciences of the teacher training school

Fig. 2. Concept map about relevant contents on silicates.

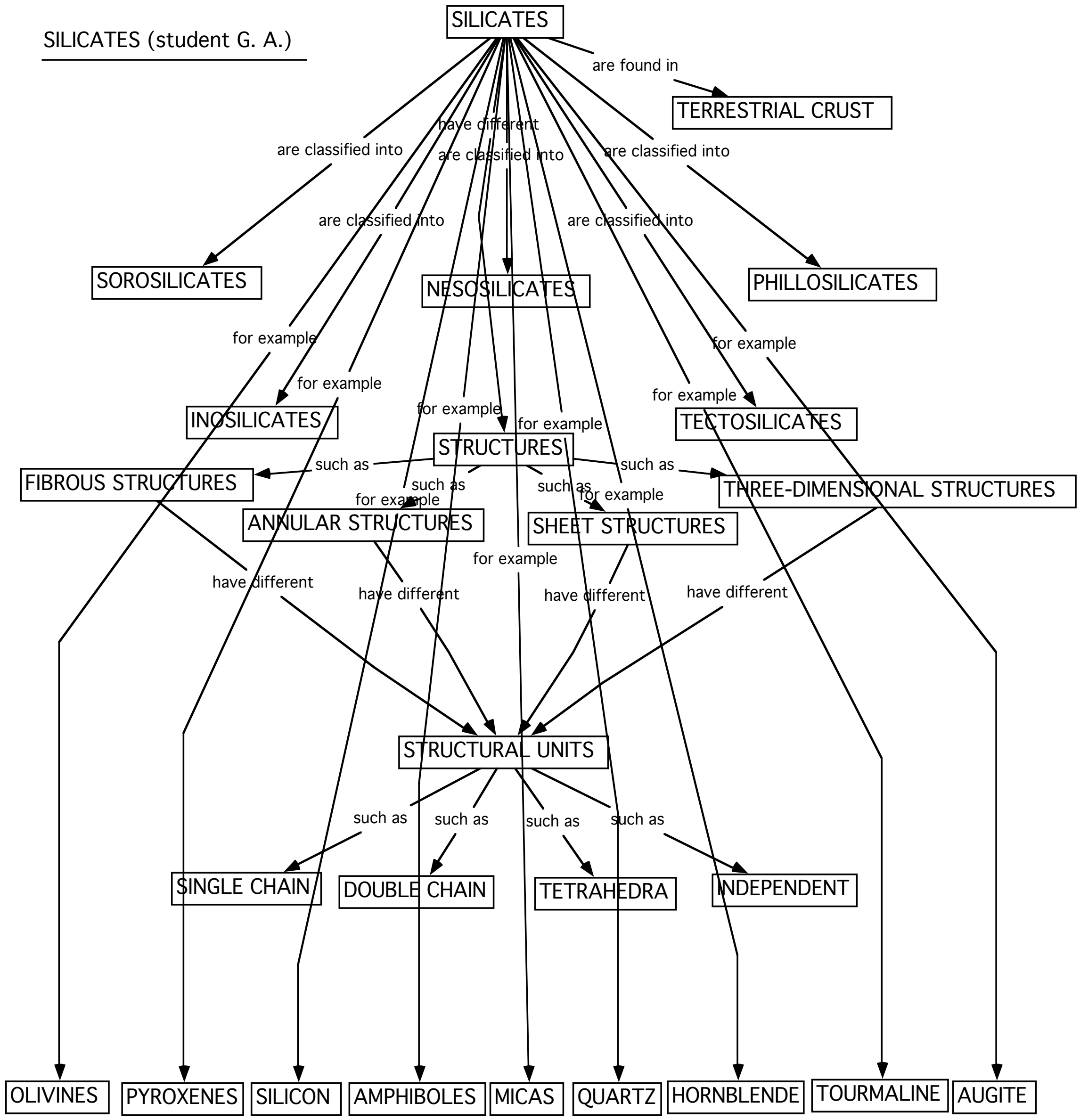

Fig.3. Concept map elaborated by the student G. A., using the same concepts as Fig.2 and without prior instruction.

Fig. 3. Concept map elaborated by the student G.A., using the same concepts as Fig. 2, and without prior instruction.

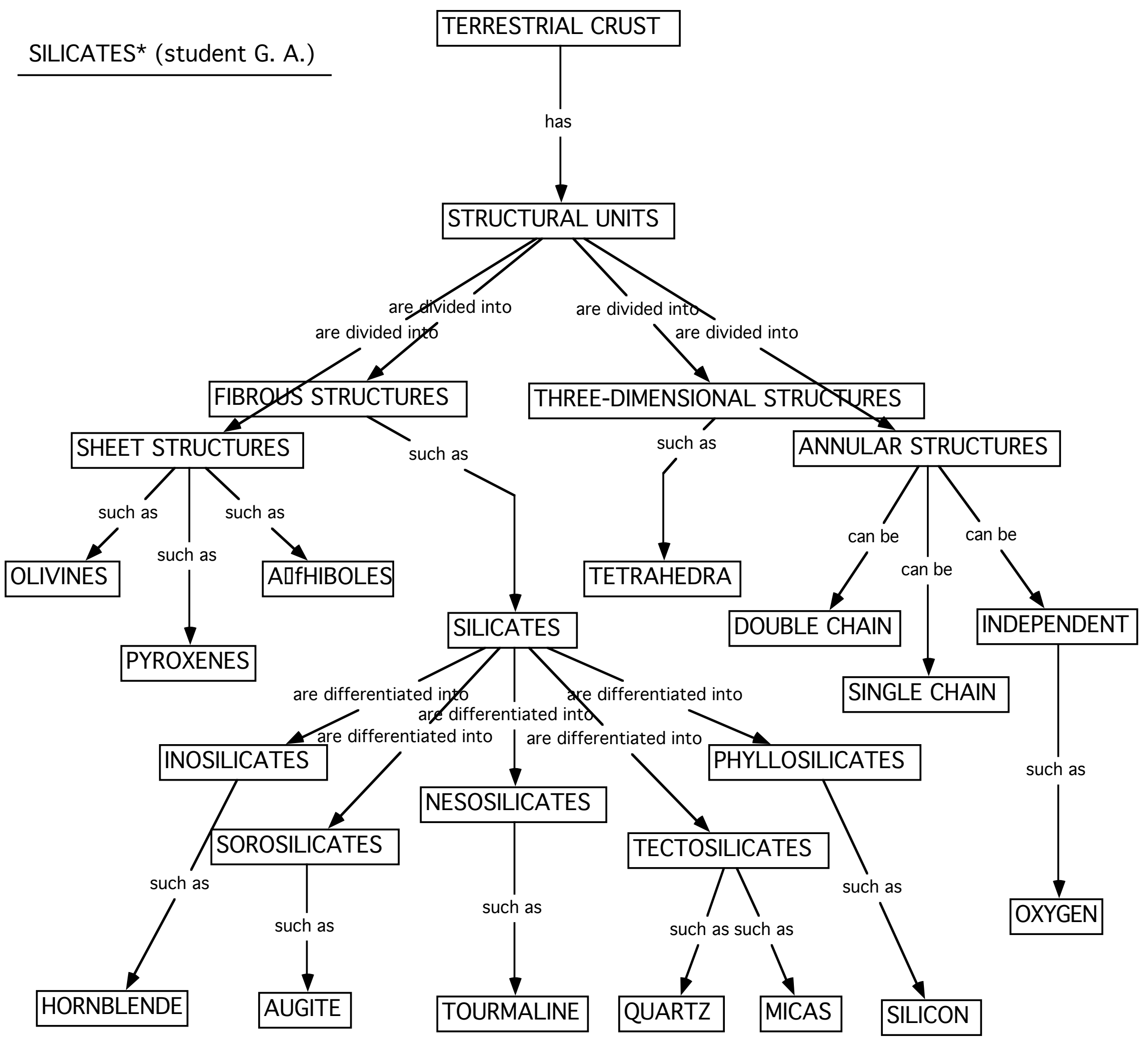

Fig.4. Concept map elaborated by the same student and about the same set of concepts as Fig.3, 1 year, 4 months and 15 days later

Fig. 4. Concept map elaborated by the same student and bout the same set of concepts as Fig.3, 1 year, 4 months and 15 days later.

ACKNOWLEDGEMENTS

I am grateful for the help and collaboration of de following teachers from the "Jose María Huarte" Primary Public School of Pamplona:
Esther ANAUT, Javier ECHEVERRÍA, Natividad IRAIZOZ, Maite MARTURET, Francisca SAGÜÉS. And, also, to my teacher of English Prof. Tommy MAC DONAGH and Mª Begoña OLAVE from *Lockhart College*

and to Ricardo SÁNCHEZ and Alberto BALLESTERO for the composition of de text and figures.

REFERENCES

AUSUBEL, D., 1968. *Educational Psychology: A Cognitive View*. (Holt, Rinehart and Winston: New York).

AUSUBEL, D., NOVAK, D. and HANESIAN, H., 1978. *Educational Psychology: A Cognitive View* (second edition). (Holt, Rinehart and Winston: New York).

AUSUBEL, D. NOVAK, J y HANESIAN, H., 1987. *Psicología Educativa. Un punto de Vista Cognoscitivo*. (Trillas: México).

BRANDWEIN, P. and PASOW, H., (eds.) 1988. *Gifted Young in Science. Potential to Performance* (National Science Teachers Association:Washington).

GONZALEZ, F.Mª., 1990. Los mapas conceptuales de NOVAK: Una técnica instruccional para la mejora de los procesos de enseñanza/aprendizaje de las Ciencias. *Príncipe de Viana.(Suplemento de Ciencias)*. Año X, Núm. 10. pp. 133-156.

GONZALEZ, F.Mª., 1992. Los mapas conceptuales de J.D. NOVAK como instrumentos para la investigación en Didáctica de las Ciencias Experimentales. *Enseñanza de las Ciencias*. Vol. 10 (2), pp. 148-158.

GONZALEZ, F.Mª., 1992. *Diseño de instrumentos didácticos para Educación Ambiental*. (Fundación Universidad-Empresa y UNED: Madrid).

GONZALEZ, F.Mª., 1992. Mappe Concettuali. Geografía della mente. *Riforma della Scuola,* 5, pp. 47-50.

GONZALEZ, F Mª y NOVAK, J.D., 1993. *Aprendizaje significativo: Técnicas y aplicaciones*. (Cincel-Kapeluzs: Buenos Aires).

GOWIN, D.B., 1981. *Educating*. (Cornell University Press: Ithaca, NY).

GOWIN, D.B., 1987, *Changing the Meaning of Experience: Empowering Teachers and Students Through Vee Diagrams and Principles of Educating to Reduce Misconceptions in Science and Math*. Paper presented at the 1987 Second International Seminar on Miscoceptions and Educational Strategies in Science and Mathematics, July 26-29, 1987, Department of Education. (Cornell University: Ithaca, New York)

HELM, H. and NOVAK, J., (eds.) 1983. *Proceedings of the International Seminar Misconceptions in Science and Mathematics*. Department of Education. (Cornell University Press: Ithaca, NY).

MOREIRA, M.A., 1992. *Aprendizaje Significativo. Conocimiento Científico y Cambio Conceptual*. Conferencia dictada en un seminario sobre "Aspectos Relevantes en la Enseñanza y Aprendizaje de las Ciencias y la Matemática", patrocinado por la Organización Iberoamericana para la Educación, Ciencia y Cultura, Madrid.

MOREIRA, M.A. y NOVAK, J.D., 1988. Investigación en Enseñanza de las Ciencias en la Universidad de Cornell: Esquemas Teóricos, Cuestiones Centrales y Abordes Metodológicos, *Enseñanza de las Ciencias,* Vol. 6(1), pp. 3-18.

NOVAK, J.D., 1982. *Teoría y Práctica de la Educación*. (Alianza Universidad: Madrid).

NOVAK, J.D., 1987. *Human Constructivism: Toward a Unity of Psychological and Epistemological Meaning Making*. Paper presented at the Second International Seminar on Misconceptions and Educational Strategies in Science and Mathematics Education. (Cornell University, Department of Education: Ithaca, NY).

NOVAK, J.D., (Ed.) 1987. *Proceedings of the second international seminar. Misconceptions and educational strategies in science and mathematics*. (Cornell University, Department of Education: Ithaca, NY).

NOVAK, J.D., 1988. Constructivismo Humano: Un Consenso Emergente, *Enseñanza de las Ciencias,* Vol.6(3), pp. 213-223.

NOVAK, J.D., 1988. The Role of Content and Process in Science Teacher Education. In BRANDWEIN, P. and PASOW, H. (eds.) *Gifted Young in Science. Potential to Performance*. (National Science Teachers Association: Washington).

NOVAK, J.D., 1989. *Helping Students Learn How to Learn: A View from a Teacher-Researcher*. A paper presented as the opening address of the Third Congress on Research and Teaching of Science and Mathematics. Santiago de Compostela. Spain.

NOVAK, J.D., 1991, Concept maps and vee diagrams: Two metacognitive tools to facilitate meaningful learning. *Instructional Science,* 19: 1-25.

NOVAK, J.D. y GOWIN, D.B., 1988. *Aprendiendo a Aprender*. (Martínez Roca: Barcelona).

SCHWAB, J., 1973. The practical 3: Translation into Curriculum, *School Review,* 81 (4), pp. 501-522.