THE NOTION OF DECOMPOSITION: A DIDACTIC RESEARCH IN LYCEUM BIOLOGICAL COURSES

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ABSTRACT: Soil is one of the most precious assets of humanity as it provides support and nutrients for plants, shelter for organisms that live in it, makes life possible. But it is a finite natural resource that is easily damaged so it needs protection and rational management as a result of education and public information ("Decalogue of Soil by the Council of Europe"). Decomposers are a consumer category, mainly fungi and bacteria, which mineralize dead organic matter and close the biogeochemical cycles, so contribute to the recycling of nutrients in ecosystems, protect the life. The project of teaching research, which is described in this paper, was part of the Lyceum course of Environmental Sciences aimed to the theoretical and practical approach of the concept of decomposition. For the preparation of theoretical teaching, it was utilized some school teaching tools and techniques, searched the synonymous and linked terms to decomposition into the Curricula and school books of Lyceum. In the field and in the laboratory, it was materialized measurements of paper decomposition rate, in the forest of the school yard. Measurements received in a sampling period of one school year, with a previous pilot phase, and after statistical analysis, exported conclusions concern the seasonal variations of the soil decomposers' action, in correlation to the weather conditions.

Key words: decomposition, school educational project, didactic research, field work

INTRODUCTION

The soil is the upper layer of the earth's crust, consisting essentially of crushed rocks and decomposed organic matter, formed by the interaction of abiotic and biotic factors. Soil is one of the most precious assets of humanity as it provides support and nutrients for plants, shelter for organisms that live in it, makes life possible. But it is a finite natural resource that is easily damaged so it needs protection and rational management as a result of education and public information ("Decalogue of Soil by the Council of Europe"). The organisms which live in an ecosystem are distinguished, depending on the way to ensure their food, into producers, consumers and decomposers. Consumers and decomposers are heterotrophic organisms (Tsounis, 1993; Adamantiadou et al, 2005).

A part of the organic matter is transferred, as food, to the consumers, while another ends up as dead organic matter (leaves, seeds, twigs, etc.) in the ground and becomes food for decomposers with dead organic material of animal origin (dead organisms' bodies, secretions, excreta etc.). Thus, a wide range of organisms (earthworms, bacteria, fungi, ants, beetles, rodents, etc.) breaking the complex organic substances in simpler, alongside the roots of plants which act mechanically and chemical (Athanasakis et al, 2005). Decomposers are a consumer category, mainly fungi and bacteria, which mineralize dead organic matter and close the biogeochemical cycles, so contribute to the recycling of nutrients in ecosystems, protect the life. Decomposers also contribute to natural and artificial ecosystems' depollution (Tsounis, 1993; Adamantiadou et al, 2005). This cleavage of chemical compounds into simpler compounds and chemical elements becomes in ecosystems with many chemical, physical and biological processes, closing the biogeochemical cycles in nature (Lykakis, 1997; Sfendourakis & Korfiatis, 2002).

The soil invertebrates play, also, vital role in terrestrial ecosystems, both through their participation in the degradation of dead organic material, and thus to the nutrient recycling process, additionally, to the improvement of the soil microenvironment conditions because of their motor activity (Grammenou et al, 2008). Degradation in the forests of Mediterranean ecosystems is very fast due to the high temperatures and humidity. But all inorganic nutrients are re-absorbed fast by plants, so soil of these forests remain, finally, poor (Adamantiadou et al, 2005).

One of the major environmental problems in Greece and worldwide, is the waste management and the impact of uncontrolled or semi-controlled discarding them on the ground. The bioremediation is a general term used to describe the destruction of the contaminants located in the soil, sludge and groundwater through biological mechanisms, with the help of microorganisms. The process involves the combined use of oxygen, nutrient substrate (dirt) by decomposers, regulation of soil moisture and other environmental factors (Geneiatakis, 2005). The paper is easily degrading and, generally, does not burden the environment as other polluting materials. Also, paper industrial production does not cost in energy so much and is not so polluting to the environment. Additionally, grant quantities of paper are recycling; even recycling is not a panacea (Lambrou et al, 2005). The cellulose, the major organic component of paper, is a polysaccharide which can be renewed since it is produced in great quantities on the earth as component of the plants' cell wall (Kapsalis et al, 2000).

In contrary, plastics degrade very slowly, but hamper the decomposition of other waste present in landfills, even their biological consequences are insignificant or extremely limited, compared with other types of pollution. There are not evolved microorganisms to degrade plastics because plastics appeared as an industrial product of the recent geological years. However, in recent years, it has been developed the technology of decomposition of the plastics by the process of photo-biodegradation. This technology is based on adding a small amount disintegrator, which imported into the plastic at the raw material production process, changing the behavior of the plastic. The degradation of the plastic begins when the planned lifetime has finished and the plastic is no longer needed (Katsaros, 2006). Plastics having been deposited for a time in the sun, even in the landfill will be degraded by bacteria and fungi, preceding the disintegrator have split the macromolecules of the plastic in much smaller, so that they can be consumed as food materials by the microorganisms-decomposers. Searching in a garbage recycling factory, researchers in Japan discovered the first known bacterium Ideonella sakaiensis 201-F6 which breaks polyethylene PET, promising much to the anti-pollutant sustainable biotechnology (Pratikakis, 2016). Humans, with the wide range of interventions on the balance of natural ecosystems, are mortgaging the planet's future, but as long as the present generation is the root of bad, equally is the beginning of the solution (Calwell, 1989).

The project of teaching research, which is described in this paper, was part of the course Principles of Environmental Sciences of the B class of the Lyceum Meleses, Heraklion (Greece), which was a selectable and not mandatory course by 20 students approximately. Project aimed to the theoretical and practical approach of the concept of decomposition by carrying out a research project. For the preparation of theoretical teaching, it was utilized some teaching tools and techniques, searched the synonymous and linked terms to decomposition and decomposers into the Curricula and school books of Lyceum. In the field and in the laboratory, it was materialized measurements of paper decomposition rate, in the forest of the school yard. The selection of content, methodology and implementation of teachings is crucial for the achievement of the course objectives, the acquisition and cultivation of knowledge, abilities, skills, self-motivation, by the students (Chatzidimou, 2010). The interactive form of teaching is a decisive step in the further activation of students' process to think consciously and responsibly on the teaching's cognitive objects. The experimental teaching is aimed primarily at cultivating of students' skills rather than on learning.

The research projects were instituted in Greek Lyceums, for first time, in September 2011 as a distinct unity of the compulsory "New School" Program (Ministry of Education 2011: 13 Government Gazette 1213, issue. B/2011). The development of inquiry teachings is in accordance with modern conceptions of the nature and orientation of curricula with many applied practices during last decades in schools and universities of other countries. As an option of educational practice, the school research projects are organically adapted to the philosophy of the "New School", which perceives the students as young "intellectuals", "scientists" and "researchers", cooperating closely in a framework of initiatives and selections, with different ways of experiential learning, through interdisciplinary approaches, experiments and investigations (Matsagouras, 2011).

METHODS

Main objective of the carried-out research was to reveal and describe an innovative teaching intervention in Lyceum which implemented in the frame of the Education for the Sustainable Development.

To serve the needs of the research, it was studied the archival material of the project in a constructed manner, of qualitative approach. It was used the content analysis of notes and notifications referred on the used curricula, schoolbooks, teacher's books and Laboratory guides of the biological courses of Lyceum, also the tables of measurements of buried in the soil paper weight and the results of statistical analysis. As the research material was studied, every phrase, paragraph, figure, photos etc., were recorded and coded in 4 main categories: Didactic Methodology, Required Material and Infrastructure, Theoretic Approach of the term 'Degradation', Measuring the Decomposition Rate The categories were not defined beforehand but adopted in the procedure of research developing and evolving data analysis resulting in the coding of data (Cohen & Manion, 1994; Iosifidis, 2003).

In the school course "Principles of Environmental Sciences" of B class of Lyceum with a group of 20 students 16-17 years old, in order to be taught the notion "Decomposition" in the Nature, the teacher selected the essay method (Frey, 2005) and applied a research project with yearly duration, which ran parallel to the rest teaching course subjects. This innovative teaching, in theoretical and experimental base, carried out in Meleses Lyceum of Crete, Greece, during the school year 2005-2006. Students and teacher materialized a bibliographic research parallel to the experimental and the educational visits.

RESULTS AND FINDINGS

For the course "Principles of Environmental Sciences" teaching demands implemented many teaching strategies, methods and techniques to cover the syllabus, in a variety of didactic ways, depending on the topic and the module. In the frame of this course, the project 'Decomposition rate in the forest soil of our school yard' carried out, with the students of B class of Lyceum, in theoretical and experimental base, with educational visits, indoor and outdoor activities which promote the inquiry based learning in Sciences.

Didactic Methodology

The factors that influence learning and differentiate the results of teaching are classified into three main categories (Charalampopoulos, 1987). The first covers the skills, motivation and students' readiness, the second the experience, adaptation and health, in the third is the method, the school atmosphere and the teacher. Students and teacher studied in depth the curricula of the biological courses of Lyceum, the schoolbooks, the teacher's books, the Laboratory guides and the corresponding circulars with the Ministerial teaching guidelines of the courses: "Principles of Environmental Sciences", "Biology A, B, C classes", "Management of Natural Resources" (Argyris et al, 1994; Barona et al, 1999; Kapsalis I et al, 2000; Adamantiadou et al, 2005; Athanasakis et al, 2005).

The implemented in the classroom teaching techniques were brainstorm, at the beginning of the course teaching, the questioning-answering and discussion. In the evaluation tests were used closed and open type questions, of multiple choice, gap filling (Athanasakis et al, 1999). There were also solved numerical exercises on the growth rate of the bacterial population in closed culture of bioreactor (Kalathaki, 2005).

The theoretical approach of the decomposition developed through the following topics given to the students for inquiring: definition of the organism's decomposers, their species (with illustrations of their action), their role and importance in the Earth, developing scenarios on "how the earth would be without decomposers or what will happen if they disappear for some reason?", the food relationship with other organizations, at what level of the food pyramid would we rank them, etc. For the needs of teaching, regarding the conceptual approach of the terms, became a limited research in the content of Lyceum curricula of Science courses.

For the experimental approach of the degradation process, it was measured the decomposition rate of buried papers in the soil, following the described exercise protocol in the Laboratory Guide of Biology C Class of Lyceum (Barona et al, 1999). The speed of decomposers' work can be measured by various methods, such as the release of carbon dioxide from the soil as well as the applied laboratory exercise. During an educational excursion, they visited a biological refining station and a landfill space of the school region.

Students worked in groups, searched the school books, carried out the samplings, materialized the measurements; they co-constructed the knowledge and shared it in the team. With the mutual teaching, they re-organized the teaching material and syllabus with personal criteria, incorporating the new knowledge into the existing cognitive structures with the most convenient way, according Slavin's theory of cognitive enrichment (Mihailidis, 2003). For the formative evaluation of the following procedure and the students' participation, developed discussions with students and teachers during the school year where clarified objectives, practices and responsibilities. In the final evaluation, at the end of school year, students expressed their thoughts, aspects and suggestions for the followings based on the Evaluation Sheet of periodic student evaluation of the Educational Research Centre and Greek Ministry of Education (KEE, 1999).

Required Material and Infrastructure

The measurement of the decomposition rate of paper in the soil of the school yard forest materialized during the school year 2005-2006. The previous school year measured only once (paper buried on 2/2/2005 and retrieved on 9/3/2005) indicatively and pilot, in order to clarify the procedure to be followed.

The laboratory used equipment were A4 paper, nylon bags for food packaging, a bradawl, a high accuracy weight balance and a drying oven. The bags used were not photo degradable. Each A4 paper sheet had dimensions 21x30 cm and weight 5g before burying (80g/m2). The weights of the paper before and after installation in the soil were measured in balance "Bonso 339-00" capacity 500g, graduation 0.1g. Each sheet was enclosed in a nylon bag of its dimensions with holes made with bradawl to have openings approximately 1/5 of the surface. The papers, enclosed in the perforated bags, buried in the soil to a depth of 10cm from the surface. The day that the papers were retrieved, on the same day the new papers were buried, starting from 02/02/05. The samplings were made on the following dates: 09/03/05, 13/05/05, 12/10/05, 02/12/05, 27/01/06, 20/03/06, 05/05/06, and 13/06/06. The wet

semi-decomposed sheets of paper, constituted the sample material, weighted (wet weight) in the retrieving from the soil, dried in an oven at 70oC for 10 hours and then weighted again (dry weight).

Statistical analysis of the measurements became by EXCEL and the results are illustrated in the Table 1 and Figures 1 and 2. The exported conclusions concern the efficiency of the soil decomposers, at times of the year.

Theoretic Approach of the term 'Degradation'

A Brainstorming, in the beginning of the project, revealed the following associated terms to degradation, combining knowledge from the rest science courses: 'death in nature (lysosomes)', 'cycle of nutrients in the ecosystem', 'energy flow in the ecosystem', 'bacteria, fungi, protozoa', 'eutrophication', 'ecosystem, habitat', 'food pyramid', 'energy pyramid', 'food web', 'food chains'.

Objectives relating to 'degradation/decomposition' in the New Curricula of General Lyceum listed as follows: to understand the necessity of matter recycling and connects it with the degradation, to describe the basic processes of the nitrogen cycle, to identify the action of bacteria (nitrogen fixation, nitrification, de-nitrification) and the role of degradation, to describe the basic processes of phosphorus cycle and recognize the importance of degradation, to distinguish the organisms to producers, consumers and decomposers with criterion the way they ensure their food. Also, it was proposed 'field study on the degradation observed in a typical ecosystem of the local environment'.

Very few references about 'degradation' were found in the searched Natural Sciences' school books of Lyceum. In the school book of Chemistry C Class for students of Positive Direction highlighted the definition of 'molecules degradation that the carbon chain becomes smaller by one carbon atom', in Chemistry B Class of Lyceum had referred 'a reaction that allows such degradation and this is decarboxylation'. In the school book of Biology of class C-Positive Direction (Aleporou, 2001) are three references to the term 'degradation'. 'In Gene regulation of prokaryotes, lactose itself activates the process for its degradation'. 'Laboratory modified types of organisms have created with properties that help the breakdown, the faster degradation. They created by combining techniques of classical genetics and recombinant DNA technology'. 'Degradation rate of oil spills by microorganisms is dependent on a range of many factors such as environmental temperature, the composition of the oil, the concentration of oxygen in the sea water and sufficient nutrients for bacterial growth'. In the school book Biology C class -General Education (Adamantiadou et al, 2005) there were 16 references to the concept of 'degradation' and 'decomposition' which are not mentioned here, for discourse and space economy.

Measuring the Decomposition Rate

During decomposition in Nature take place many and varied changes related to, and affected by many factors. Particularly, temperature influences more the speed of the chemical reactions occurring in the degradable materials and the functions of microorganisms that carry it out. Also, moisture effect the decomposition rate, since water hydrolyzes the biological macromolecules degrading them into smaller, and offers to the environment all the demanded chemicals, which absorbing by the plants, will pass to all organisms, through the feed paths (Lykakis, 1997; Geneiatakis, 2005; Athanasakis et al, 2005).

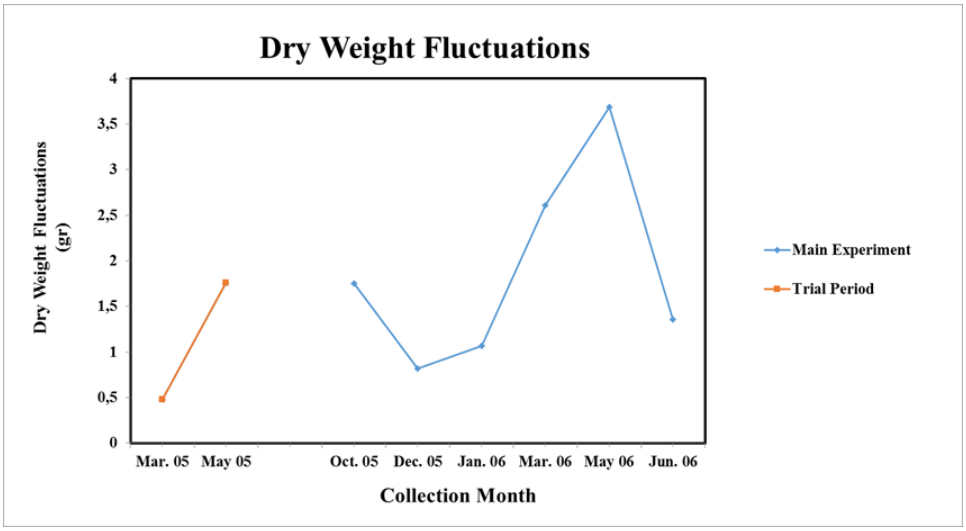
Table 1. Changes of buried paper weight during the research period

Bury Date	Collection Date	Days in soil	Wet weigth (g)	Dry weigth (g)	Moisture (g)	Change of weight (5gr-dryw)	% Change of weight	Decomposition rate mgr/day
2/2/2005	9/3/2005	35	7,48	4,52	2,96	0,48	9,6	13,71
9/3/2005	13/5/2005	65	4,78	3,24	1,54	1,76	35,2	27,08
18/9/2005	12/10/2005	24	4,67	3,25	1,42	1,75	35	72,92
12/10/2005	2/12/2005	51	8,61	4,18	4,43	0,82	16,4	16,08
2/12/2005	27/1/2006	56	10,68	3,93	6,75	1,07	21,4	19,11
27/1/2006	20/3/2006	52	5,43	2,39	3,04	2,61	52,2	50,19
20/3/2006	5/5/2006	46	2,17	1,31	0,86	3,69	73,8	80,22
5/5/2006	13/6/2006	39	3,98	3,64	0,34	1,36	27,2	34,87

The values of paper wet and dry weight, got during the sampling periods, are illustrated in the Table 1. The same Table contains the % changes of the weight and the concluding contained moisture also the calculated seasonal

decomposition rate of paper. The upper two rows of Table 1 contain the results of the pilot phase of the research, in the previous school year on the dates of 02.02.2005 and 09.03.2005.

The figure below (Fig.1) shows the results of data analysis regarding the changes in the weights of the buried papers during the research period (blue line). The red line corresponds to the results of the pilot phase of the research, in the previous school year, on the dates of 02.02.2005 and 09.03.2005.



As it is apparent from the values in Table 1 and the schemes in Figure 1, wet weights are higher in winter and spring, once the soil is too wet due to the rain. The column of Table 1 with the mean amount of moisture in the samples of paper can be correlated with the soil moisture, revealing its seasonal variation depending on the waterfalls and air conditions.

The soil that was stuck on the hauled papers, inside the bags, hardly could be removed, due to the moisture which made it sticky on the paper. This is another reason of increased wet weights in the autumn, winter and early spring, periods of rainfalls in Crete. Regarding the sampling of 02/12/15, it had much rain during the previous three days, therefore recorded such high wet weight values. This soil was humus, organic matter mainly plant origin, under partial decomposition in the upper soil layer. This material holds moisture and soluble nutrients to a natural fertilizer (Lykakis, 1997). The sampling papers during the winter months, was extremely wet and white, had yellowed only around the openings of the bag. In autumn, paper was all yellowed; the decomposition had progressed and spread inside the pouch, even where there were no openings.

The average dry weight of the sample ranged from 1,31g (5/5/06) to 4,18/4,52g (12-10-05/2-2-05) with the highest value of the decomposition rate to be 80,22 on 20-3-06 and 72,92 on 18-9-05 mg/day, spring and winter, when the soil moisture is high because of the rainfalls and the temperature relative high (Table 1). The lowest values were recorded in winter, obviously affected significantly by the very low temperatures, were 13.71 mg/day on 2-2-06. In Crete, January and February are, generally, very cold months. As for the variation in the seasonal rate of decomposition, it is clear that the daily rate significantly depends on the seasonal variations of temperature and soil moisture, with the prerequisite of high humidity exist, as also Argyris et al (1994) refer in an analogue research. The rate reaches at the lowest prices in winter, increases in early spring, and in the autumn, rises again significantly (Table 1). During the summer, there were no survey data because the schools were closed.

A similar experiment described in school book Biology C class 2nd Bundle (Argyris et al, 1994) where researchers sunk in the Hymettus of Attica, Greece, ground filter paper enclosed in perforated bags for measuring the decomposers' activity. The rate of reduction of the initial paper weight showed that cellulose degradation has different rates in different seasons. Decomposition was faster in the early autumn, when drought ceased to be a limiting factor and in late spring when the temperature no longer was a limiting factor.

In Mediterranean climates, like Crete, where the sun and wet winters alternating with warm, long and dry summer, intense decomposing activity observed at the time of the high temperature associated with water availability, high soil moisture, and even the moisture preceded, that the chemical bonds in molecules of paper cellulose to weaken and break down readily.

The school curriculum subjects have much to offer to the Education for the Sustainable Development, although issues related to Sustainable Development, can rarely be addressed exclusively through a single subject. Natural Sciences provide concepts and mechanisms, models and structures students to understand the complexity of life in nature and how much environmental issues are multifactorial (Flogaiti & Liarakou, 2009). As the first institutionalized application of the Research Projects in Lyceums happened long after the implementation of the discussing project, the described teaching intervention 5 years before was an innovation in school teachings. Now, teaching by Projects in Greek Lyceums, has become a substantial educational innovation, based on modern and proven pedagogical principles, introduced to Lyceums and Gymnasiums in 2011 as compulsory courses, aiming to enhance the educational role of the "New School".

CONCLUSION

The theoretical and experimental approach of the term 'degradation' in the course "Principles of Environmental Sciences" of B class of Meleses Lyceum aimed to a different way of teaching about the role of decomposers in the biogeochemical cycles of nutrients and energy flow in the ecosystems. In the course, during the school year, utilized heterogeneous research formats combined with qualitative and quantitative methods, such as documents' discourse analysis, field and laboratory measurements.

The didactic research revealed very few references to the notions 'degradation/decomposition', dispersed and fragmented in school books, curricula and laboratory guides of Natural Sciences' courses of Lyceum. As for the variation in the seasonal rate of soil decomposition, it became clear that the daily rate significantly depends on the seasonal variations of temperature and soil moisture, following the changes of Mediterranean climate.

RECOMMENDATIONS

The implementation of Projects in Schools contributes to changing traditional attitudes of teaching, learning, practices, roles and culture in schools. Associated with teaching objectives of school curricula, can be approached subjects of other courses, of different areas in schools, with interdisciplinary approaches an contribution of different specialties of teachers and scientists. The pedagogical profit is double, as students acquire deep knowledge at functional level of understanding the studying issues, while at the same time, with their systematic involvement in research processes, develop attitudes and cognitive-methodological abilities of investigation and management issues and situations (Matsagouras, 2011).

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