Development of an Active School Intervention in the Field of Environmental Microbiology

[a]Maria Manuel Azevedo, [b]Cássio Fernanda
[a]School E.B. 2,3 D. Maria II, Rua da Alegria, 4760-067 Vila Nova de Famalicão Portugal
[a]Department of Microbiology, Faculty of Medicine, University of Porto;
[b]Centre of Molecular and Environmental Biology (CBMA), Department of Biology, University of Minho, Campus de Gualtar, 4710-057 Braga

Corresponding author:
Maria-Manuel Azevedo
School E.B. 2, 3 D. Maria IIVila Nova de Famalicão**,** Portugal

Abstract

To value active learning, we carried out an "Active Discussion" activity based teaching strategy focusing on Environmental Microbiology. With this activity, we aimed to identify student´s difficulties and to create conditions to help students to acquire deeper knowledge in the eco-physiology of a particular group of fungi (aquatic hyphomycetes) with relevance in the ecology of streams. The efficacy of this "Active Discussion" was evaluated by a questionnaire applied to the students before and after its implementation. This study aimed to evaluate: 1) the knowledge of students on a specific environmental issue; and 2) evaluate the efficacy of the "Active Discussion" in improving students' knowledge and interpretation skills on environmental biology. This study allowed us to conclude that this teaching intervention was efficient and might be regularly implemented in Secondary Schools.

KEYWORDS: active school teaching intervention, aquatic fungi, heavy metal pollution, microbial ecology, science education.

INTRODUCTION

Science education should aim to develop rational and critical thinking, must be interdisciplinary and allow understanding and relating "Science, Technology and Society". Thus the idea of searching and finding should be a continuous process, a daily attitude and not an isolated act. Only by this way we will form active citizens, with scientific literacy, fundamental aspect to discuss consciousness scientific and technological issues that today's society raises essential condition for the exercise of citizenship Sequeira, (1996). In a rapidly changing society in which future changes are unknown, the School has a moral obligation to prepare young people for the new challenges (Giordan *et al*., 1988). In this perspective the new curricula value, among other things, methods of active teaching/learning based on interpretation and problem solving. However, reality shows that the current teaching practices remain oriented towards the transmission and storage of information Tenreiro-Vieira (2004). In this study, it was implemented an active learning methodology "Activity of Discussion" to help students to acquire knowledge, and develop skills of observation, interpretation and analysis on environmental microbiology field. This activity was implemented after the application of a questionnaire (pre-test), because were detected some gaps in

the knowledge and understanding of concepts and difficulties in terms of application and analysis capabilities. The main objectives of this research were: i) provide a reflection on current environmental problems; ii) evaluate the knowledge on current environmental problems; iii) develop skills of interpretation and problem solving; iv) assess the efficacy of the "Activity of Discussion"; and v) provide know-how related to the ecological importance of a particular group of aquatic fungi, namely aquatic hyphomycetes.

Justification for the choice of the methodology

In this study, it was implemented an "Activity of Discussion" with the help of a slide show presentation, that allowed a greater interaction between teacher/student and student/student. Moreover, compared to theoretical education, this type of methodology allows students to make more questions, thereby facilitating the construction of knowledge. Moreover, the discussion motivates students for further studies and develops "thinking skills" McKeachie (1972), also allows to increase the attention span of students relatively to the traditional teaching. Active learning can include activities such as answering questions, analyzing a chart, interpretation an observation of an experimental result. Felder & Brent (2003), advise that this practice is carried out individually or in groups and set a time period for responses. This type of learning helps to improve attitudes and abilities including reasoning Bonwell & Eison (1991). According to Piaget, (1996), new stimuli establish a relationship with the prior cognitive structure generating new knowledge, new experiences and provide intellectual growth. According to the Portuguese National Curriculum the perspective of teaching science should not be only the transmission of knowledge, but should be the creation of environments of teaching/learning favorable to the construction of knowledge and know-how. In this perspective was designed and implemented an "Activity of Discussion" presented in one Conference Azevedo (2007/a). In this conference, it was proposed its implementation on the ground. The activity was proposed for students of the 12^{th} grade because at this level of education students are familiar with the issues discussed in that activity.

Description of the biological material used and information on the tested toxicants

Aquatic hyphomycetes (HA) are filamentous fungi characterized by the production of a great amount of asexual spores or conidia, generally large, displaying characteristic shapes, sigmoid and tetra-radiated. HA are considered the main fungal decomposers of plant litter in streams as they are capable of degrading the major polysaccharides of plant cells Suberkropp, (1998), making them more palatable for detritivorous invertebrates Bärlocher (1992). Several studies have shown that the occurrence of HA in rivers is affected by physical/chemical characteristics of stream water and riparian vegetation. These organisms can be found in well-aerated non-polluted streams Suberkropp, (1998) as well as in polluted streams Pascoal & Cássio, 2004; Pascoal *et al*., (2005). It is known that anthropogenic activities affect freshwater ecosystems Merian, (1991). Among the pollutants found in rivers, heavy metals are of particular concern because of their persistence after an event of contamination, since these elements are not biodegradable and accumulate in aquatic biota. Among heavy metals, copper, nickel and zinc are considered trace elements. With respect to other heavy metals, such as cadmium and lead, it is not recognize any biological function Gadd, (1993), having even a major mutagenic and carcinogenic potential.

MATERIALS AND METHODS

Population and sampling

A convenience sample was used in this study. Information about possible confounders such as socio-economic status and intellectual level, was not collected. The sample comprised 45 students of 12th grade from the area of Science and Technology. Approval for this study was obtained from the directors of the Schools involved.

Questionnaire

The level of students' knowledge was evaluated through the application of a questionnaire before and after the "Activity of Discussion". The time between the implementation of this activity and the post-test application was 2 months. The questionnaire was developed by the authors of this work, and completed anonymously by the students during regular classes with a time limit of 30 min. The percentage of voluntary compliance was 100%. The students belonged to two schools, 21 students from the High School Camilo Castelo Branco (CCB), aged between 17 and 19 years, and 24 students from Didáxis S. Cosme (DSC), aged between 17 and 20 years. The students included in this study had medium/high ratings, taking into account the marks obtained in the subject of Biology 1st period, which was confirmed by analysis of the results to the same subject in the 3rd period. The final average ratings in the subject of Biology in the 3rd period was 14.4±3.58 values for CCB students and 15.4 ± 2.81 values for the DSC students.The CCB is an Official School located in the center of the city of V. N. Famalicão, where students are mostly living in the city; the DSC is an Education Cooperative in which students are mostly from rural areas. It was found that students at DSC have additional classes during the school year when teachers detected difficulties.

Collection and processing of data

The data collection was processed in the context of the classroom without advanced notice. The main objectives of the questionnaire were: i) to gather views on relevant issues on the environment, including aspects related to pollution, ii) to evaluate knowledge in the areas of microbial physiology and ecology, and iii) to assess skills of interpretation and analysis. After analyzing the results of the pre-test, the "Activity of Discussion" was built and implemented with the help of a slide show presentation. Students were transported to a real situation: "Portuguese stream pollution caused by heavy metals." During this educational intervention (2 sessions lasting 90 minutes), each student was informed that they would be assessed for the content explored in these sessions, but were not informed of the assessment instrument to be used. Two month after the completion of this activity, the students completed a questionnaire (post-test) identical to the pre-test. Each of the questions was analyzed separately and classified as correct, partially correct or incorrect. The number of correct answers, partially correct and incorrect was converted into percentage. Pearson's Chi-square ($\chi 2$) was used to determine whether there were statistical differences between the responses obtained in the pre- and post-test ($p<0.05$), using the SPSS software (Version 14.0. SPSS Inc., Chicago, IL, USA).

Brief description of the school intervention

The educational intervention was structured in three successive stages. The first consisted in the questionnaire (pre-test). The second step was the implementation of the "Activity of Discussion". At the beginning of this activity, an informative text was provided to the students about the role of aquatic hyphomycetes in freshwaters. The "Activity of Discussion" was presented and discussed with the aid of a slide show presentation constructed by the authors of this manuscript and followed by students on paper. The explanation of the methodologies adopted for each type of experiments (fungal sporulation and growth in solid and liquid media), was complemented with a visualization of laboratory equipment used in these experiments, fungal cultures on

solid medium and observation of spores of several aquatic hyphomycetes with optical microscope. During the completion of this activity, the teacher (MMA) adopted the posture of guiding learning, providing clues and asking questions to promote discussion among students. For example, students were asked about the need to use checks and the importance of using replicates in scientific experiments. To validate this activity, the students were subjected to a questionnaire (post-test). The responses were analyzed and compared with those of the pre-test. The pre and post-test was divided into 3 parts, covering 1) general issues, 2) more specific questions (e.g. differences between essential and non-essential metals, type of metals, importance of fungi as decomposers, distinction between modes of reproduction: sexual and asexual), and 3) one question for applying knowledge in a real situation, which consisted of an experimental design on the use of fungi in processes of bioremediation.

RESULTS

In the pre-test the responses concerning general environmental issues showed that 65% of students from the Secondary School Camilo Castelo Branco (CCB) were well informed on environmental issues, and that fact was attributed to information obtained from TV and School (74%), TV and newspapers (17%) and TV and movies (9%) (Table 1). Results of students from Didáxis (DSC) showed that only 54% of students were well informed on these subjects. These students have a more diversified view on the sources of information (Table 1).

Still on the environmental issues, students from CCB were concerned with the problem of water quality, with 48% of students reporting water quality as the main environmental problem. However, 96% of students from DSC considered the water quality a key priority aspect. Concerning sources of water contamination, 44% of the CCB students refer industry as the primary source, followed by leisure activities (30%), agriculture (13%) and mining activities (13%). Students from DSC also elect the industry (75%) as main source of contamination followed by leisure activities (17%) and urbanization (8%). In order to know the attitude that students would take to face a real problem of water contamination we simulated a discharge situation of industrial pollutants into a river. Students were asked on which options to take to face this situation. The choices considered by the authors were: close the factory, forcing the owners to clean up the river, forcing the owners to pay fines until solve the problem, take time to solve the problem without imposing fines, and do nothing. The options chosen most often by the students from CCB were forcing the owners to clean up the river (52%) and force the owners to pay fines until solve the problem (22%). The students from DSC selected the same options. In the post-test answers to general questions, such as the level and sources of information on environmental issues, environmental problems, and major sources of water contamination, remained the same relatively to the pre-test for students from both schools. Regarding the more specific aspects, we noticed that, when in the pre-test we evaluated students' knowledge related to heavy metals, such as the distinction between essential and nonessential metals, 61% of students from CCB did not respond and only 17% respond correctly (Table 2). With regard to the students from DSC, 59% answered correctly, 33% incorrectly and 8% did not respond (Table 2). The mistakes made were basically two: the students stating that "All heavy metals are not essential" and "Essential metals even at high concentrations are not pollutants." The statistical analysis showed that students' results improved significantly from the pre- to the post-test (CCB, $p<0.001$; DSC, $p = 0.008$). Regarding the classification of heavy metals,

70% of students from CCB rated incorrectly, 26% did not respond and only 4% rated them properly. Students from DSC showed more knowledge at this level, given that 59% answered correctly, 33% incorrectly, and 8% did not answer. Among the mistakes made by students from both schools we highlight the fact that they have considered Pb and Cd essential metals and Zn, Cu and Ni nonessential metals. In the post-test all the students from CCB distinguished and classified correctly essential and nonessential metals. Regarding the DSC students, 92% achieved this objective. Regarding this issue, students from DSC and CCB improved significantly their performance ($p<0.001$ and $p =0.008$ respectively).

Regarding the question "What do you mean by fungus", 52% of students from CCB answered incorrectly and 30% correctly (Table 3). The most frequent mistakes were: they considered fungi exclusively unicellular or multicellular; and they claimed that fungi belong to the Protist kingdom, and declare that these organisms are producers. Students from DSC showed similar results, 59% answered incorrectly and 29% correctly (Table 3). The most frequent mistakes were the same, with the addition that some students claimed that: "Fungus is a species of bacteria that decompose organic matter in mineral matter".In the post-test, 83% and 92% of the students from CCB and DSC respectively showed right ideas about the main characteristics of a fungus. Furthermore, students' knowledge improved significantly in the post-test ($p<0.001$) (Table 3).

Regarding the importance of fungi as decomposers of plant litter in streams, in the pre-test 57% of the students from the CCB responded incorrectly and 40% correctly. The mistakes were mostly due to the fact that students do not possess an accurate scientific language and have a fragmented knowledge. As example, we can cite the fact that students claimed that it was a natural way to clean up rivers, fungi feed on heavy metals, fungi decompose all types of residues, and fungi are important organisms exclusively due to its involvement in food production particularly in the manufacture of bread and wine. Students from DSC school have more presented the role of fungi as decomposers because 75% answered correctly and 4% partially correct, the others did not respond. Students who respond partially correct claimed that fungi are important because they decompose matter, however were unable to identify the type of material, others claimed that they are involved in biological remediation but also were unable to explain what this means. Regarding the importance of fungi as decomposers, 87% and 83% of the students from CCB and DSC, respectively, were able to answer correctly in the post-test. The results from the CCB students improved significantly ($p<0.001$). Over the DSC students this trend was less evident ($p=0.544$), given that 75% of the students had already answered correctly on the pre-test. Regarding the distinction between sexual and asexual reproduction, in the pre-test all students from the CCB, and 83% of the students from the DSC answered correctly (Table 4).

At the post-test all the students from both schools answered correctly. Regarding the concept of sporulation, in the pre-test, 22% and 54% of the students, respectively from CCB and DSC demonstrated knowledge about this process (Table 5). In this respect, there has been a large increase in the knowledge between the pre- and post-test, given that 74% of the students from CCB ($p=0.001$) and 100% of the DSC ($p <0.001$) answered correctly (Table 5).

When we searched students' knowledge regarding the relationship between asexual reproduction and genetic variability, in the pre-test we found that 91% of the students from CCB and 79% from DSC explained correctly this relationship (Table 6). The students who answered incorrectly stated that asexual reproduction did not ensure

genetic variability, which was not critical to the evolution of the species. In the post-test this issue was commented in a clear and explicit form for all students of both schools (Table 6). However, the differences between the pre- and post-test were not statistically significant (CCB p= 0.350 and DSC p=0.061), despite the developments in the answers given by the students from the DSC were very close to the significance.

Data provided to the students indicated that certain fungi accumulate heavy metals, in this sense; the last question forecast the design of an experiment in microcosms using aquatic fungi for application in bioremediation. The analysis of the answers showed that 87% of the students from CCB did not respond, and 13% did so with serious inaccuracies (no experimental controls, improperly formulated hypotheses, no replicates (Table 7). Students from DSC also had plenty difficulties in resolving this issue, only 12% drew experiments, although with gaps regarding the proper application of the scientific method (Table 7). The main difficulties detected in the students of both schools were linked to a deficient planning of experiments, the lack of controls regarding important parameters such as temperature, pH and aeration. Other difficulties were related to insufficient explanation of ideas. Students refer "picked up polluted water" but do not indicate the type of water pollution neither the base to select the donor sites". At the post-test, most students from the CCB did not answer (82%) and justified it on the basis of lack of time, the remaining, 18% correctly designed experiments showing enough imagination, and they proposed the use of "cocktails" of species more resistant. They proposed experiments with contaminated water with one or more metals reflecting as much as possible the reality, and mentioned the need for controls (water pH, temperature and nutrient composition) (Table 7).

Significant differences between the pre and post-test were found (p=0.03). Since the majority of students from CCB reported that they did not answer to this question for lack of time, 15 additional minutes were available for the students from the DSC. The results obtained with this group were significantly better ($p<0.001$), with 79% of the students successfully designing experiments (Table 7).

DISCUSSION

The relevance of Biology has been recognized due to its influence on the quality of life of people and organization of societies. New problems require several alternative decision making at techno scientific, political, social and ethical level. In this sense, it is essential to focus on students' scientific literacy. The need to increase scientific literacy has received recognition from the Ministry of Education to make it explicit in guiding documents of the teaching/learning process "National Curriculum for Basic Education-Essential Skills" Departamento da Educação Básica – DEB, (2001). A study, conducted with 2075 Portuguese spread across different school years, showed that only 37% of respondents had a relationship with Science characterized by a significant degree of proximity Costa *et al*., (2002). In this sense, in terms of teaching/learning the great challenge facing to the teacher of the XXI century will be adapt the scientific knowledge to the learning contents Shulman, (1987). Currently, teachers are "cooks of knowledge" but preparing food for a crowd without appetite Cury, (2004). In this context, active methodologies have to be implemented. These methodologies awake in students a greater responsibility, involving them actively, challenges them to think for themselves by promoting the sharing of ideas Revans, (1982). We believe that such activities are essential to develop students skills related to the application of the scientific method, including interpretation skills and critical

analysis before new situations, making students active citizens and capable of intervening in society. According to Borges & Lima (2007), contemporary society requires rethinking the methodological strategies to overcome the pedantic lesson, replacing it with pedagogical practices that can assist the formation of a competent subject. Many students come to the classroom with considerable experience in environments of passive teaching, however it is expected that students show knowledge in active teaching, being planned their participation. In this case the role of the teacher becomes a learning mentor, being students responsible for their own learning Michael & Modell, (2003). In the case of discussion activities, as proposed in this work, the teacher should be a facilitator of learning, in this sense, the students' opinions are very important because they give opportunity to promote discussion. The discussion activities are an added value for students, in that they point out problems, misconceptions, exhibit knowledge and uncover faults Michael & Modell, (2003). In this work, a pre-test was applied in order to diagnose knowledge and skills related to laboratory setting such as the ability to formulate hypotheses, interpret and analyze experimental data. In order to fill knowledge gaps detected and motivate students for experimental work, we implemented an "Activity of Discussion" based on the results obtained by Azevedo, (2007/b). This activity motivated very much the students, since they were interested and engaged. Students followed with curiosity and interest the explanation of the methodologies adopted, noting the materials used and trying to understand the techniques used in order to carry out these experimental procedures at the School in the future. In this activity were recalled and emphasized concepts taught in 11^{th} grade, including those related to the modes of reproduction of microorganisms. Later, the students concluded that asexual reproduction although not contribute to the genetic variability of populations, ensures its rapid growth and colonization in favorable environments, with a particular focus on aquatic hyphomycetes dispersion in streams. Concepts such as unicelularidade, multicellularity, prokaryote and eukaryote were also revised. Regarding the concepts related to heavy metals, these were subject of further exploration as these contents were never studied mainly by the students of CCB. In this respect, students had very positive results at post-test, especially those of CCB. In terms of experimental design the prominence was given to the proper application of the scientific method. Using aquatic hyphomycetes as biological material, and as these organisms can accumulate significant amounts of metals; these organisms appear to be promising for future use in bioremediation. Students learned and/or reminded how to formulate hypotheses and how to design controlled experiments in the laboratory. During the discussion, several questions were raised, as why the activity was carried out with heavy metal and not with other pollutants. It was explained to the students that performing these experiments with heavy metals was related to the fact that these are the pollutants that cause major damage in freshwater streams nowadays. Students proposed the use of these fungi to test the biodegradability of other pollutants, such as hydrocarbons, since they are a major contaminant of the ocean. Another important aspect of this discussion was the mobilization of students to local issues with global relevance. This activity is presented as a concrete proposal to help teachers to develop dynamic diversified learning, particularly those that presuppose the development of interpretation skills, analysis and synthesis. We propose that this activity could be integrated into the 12^{th} grade in the subject of Biology. As well as developing knowledge teaching Science should promote reflection, opening new horizons and encouraging students to research. In conclusion, the transformation of information into knowledge and

knowledge into experience should be one of the functions of the current teachers Shulman, (1987).

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Table 1. Main sources of information on environmental issues for students from the school of Camilo Castelo Branco (CCB) and Didáxis de São Cosme (DSC)

Source of information	School	
	CCB	DSC
TV and School	74%	42%
TV and newspapers	17%	8%
TV and movies	9%	-
School	-	21%
TV and advertising campaigns	-	9%
TV and family	-	4%
TV, School and advertising campaigns	-	4%
Schools and advertising campaigns	-	4%
Newspapers and School	-	4%
TV	-	4%

Table 2. Responses of the students from the school of Camilo Castelo Branco (CCB) and Didáxis de São Cosme (DSC) about the distinction between essential and nonessential metals

Essential and nonessential metals	Pre-test		Pos-test	
	CCB	DSC	CCB	DSC
Correct answer	17%	59%	100%	92%
Incorrect answer	22%	33%	-	-
No answer	61%	8%	-	8%

Table 3. Answers on the "Definition of fungus" by students from the school of Camilo Castelo Branco (CCB) and Didáxis de São Cosme (DSC)

Definition of fungus	Pre-test		Pos-test	
	CCB	DSC	CCB	DSC
Correct answer	30%	29%	83%	92%
Partially right answer	-	4%	-	-
Incorrect answer	52%	59%	-	-
No answer	18%	8%	17%	8%

Table 4. Answers on the distinction between sexual and asexual reproduction of the students from the school of Camilo Castelo Branco (CCB) and Didáxis de São Cosme (DSC)

Distinction between sexual and/asexual reproduction	Pre-test		Pos-test	
	CCB	DSC	CCB	DSC
Correct answer	100%	83%	100%	100%
No answer	-	17%	-	-

Table 5. Answers about the concept of fungal sporulation of the students from the school of Camilo Castelo Branco (CCB) and Didáxis de São Cosme (DSC)

Concept of fungal sporulation	Pre-test		Pos-test	
	CCB	DSC	CCB	DSC
Correct answer	22%	54%	74%	100%
No answer	78%	46%	26%	-

Table 6. Answers on the relationship between asexual reproduction and genetic variability of the students from the school of Camilo Castelo Branco (CCB) and Didáxis de São Cosme (DSC)

Asexual reproduction and genetic variability	Pre-test		Pos-test	
	CCB	DSC	CCB	DSC
Correct answer	91%	79%	100%	100%
Incorrect answer	4%	17%	-	-
No answer	5%	4%	-	-

Table 7- Answers on the correct planning of experiments in microcosms of the students from the school of Camilo Castelo Branco (CCB) and Didáxis de São Cosme (DSC)

Design experiments in microcosms	Pre-test		Pos-test	
	CCB	DSC	CCB	DSC
Correct answer	-	-	18%	79%
Partially right answer	13%	12%	-	-
No answer	87%	88%	82%	21%