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PARTICULAR PEDAGOGICAL TOOLS FOR TEACHING A PRACTICAL COURSE THAT INVOLVES UNPREDICTABLE HEALTH RISK

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The metabolic processes of various microorganisms in an activated suspension cannot be easily explained. Specific pedagogical tools must be used in case of practical courses that include some health risk. As an example, the study presents an experiment in order to explain basic concepts in microbiology science and their application in environmental engineering focusing on unpredictable health risks. Passport interfaces from Turbidity Sensor, Pasco Scientific, allow students to visualize and remark all experimental steps. In this case, all particular observations can be performed after the microorganisms become activated. The study also reviews instructional frameworks for integrating tools which are essential for teaching a practical course that presents several unpredictable health risks. Supporting pedagogical materials that resulted from our study case are also detailed in order to respect the particularities of this educational context. Therefore, the pedagogical approach set up becomes an innovative model for teaching practice that involves the health risk. Also, these will be correlated with modelling and simulation of microbiological processes.

Keywords: Microbiology, Turbidity, Unpredictable health risk, Pedagogical tools.

Introduction

Microorganisms which are spread all over the soil, water, air form a heterogeneous group from the point of view of their morphology, biological activity and systematic position (Gray and Head 2008).

The study of metabolic processes of microorganisms allowed their wider use in the industry. The protein crisis led to the recovery of waste from agriculture (starch, cellulose, molasses) as animal feed. Cultivation of yeasts and bacteria on different nutritional substrates in special bioreactors has partially solved this protein crisis (Braude and Rhodes 1977). Proteins obtained from dry yeast *(Candida lypolitica*) and grown on different substrates are used in the dairy industry, meat, wood and paper industry. In England, the cultivation of the *Methylophilus methylotrophus* bacteria on methane or methanol generates an annual output of 50.000 tons of protein and low power consumption (Braude and Rhodes 1977). The 1970s energy crisis resulted in obtaining ethyl alcohol by cultivating microorganisms on various nutritional substrates (cellulose, starch, molasses, lignin, fat). The mixture of 80% gasoline and 20% alcohol known as biodiesel is used in internal combustion engines (Ma et al. 2013). The introduction of selected microorganisms in the mining industry for the oil recovery increases the operating efficiency (Hawkins et al. 2013). Sulphur-oxidizing and iron-oxidizing bacteria were used in biometallurgy to solubilise non-ferrous metals (zinc, copper) from the poor deposits (Beech et al. 1996).

Methane bacteria have been used for the anaerobic fermentation of organic waste with production of biogas (a mixture of 60% CH_4, 30% CO_2, 1% H_2S) (Starr et al. 2012).
The industrial production of useful compounds and substances for humans (vitamins, antibiotics, hormones, interferon), solving acute problems humanity is facing today (energy and food crisis) make this group of organisms extensively studied (Demain 2000; Ma et al. 2013; Missottena et al. 2010; Øverland et al. 2010).

Studying the behaviour of microorganisms is difficult, and it requires a special infrastructure and appropriate facilities. The most important condition in the study of microorganisms is to isolate them in pure culture and create artificial culture media for them, specific to metabolic needs (Măzăreanu 1999).

Students usually participate in experiments which are carried out in the microbiology lab and are meant to reinforce their theoretical knowledge. However, in the classical context of their evolution, they may face a number of hazards and risks (e.g. combustion, contamination). Therefore, they must have knowledge about the use of chemicals and machinery when practical activities are carried out. In order to prevent risks general and safety protection rules must be respected in respects as the following ones: wearing personal protective equipment (gown, goggles and gloves), working in the lab hood and avoiding substances hazardous to health (Zaki 2010).

In this context, the lab becomes a collaborative and interactive learning environment which can greatly enhance the quality of results by the integration of appropriate teaching aids. At the same time, it must be a safe learning environment which can offer students beliefs and certainties about the preservation of their health and about not being exposed to any category of risk.

The concern for the identification, selection, acquisition, integration and exploitation of modern teaching means in practical classes is a constant of optimizing the learning process. It is correlated simultaneously with the evolution of engineering, technology and learning technologies on one hand, and the increasing challenges related to the correlation between the theoretical and the practical application of any curriculum, on the other (Avdic 2014; Hawkins et al. 2013).

There are some studies aimed at investigating different aspects of health education from a pedagogical perspective (Duan and Fortner 2010; Kublńska and Pańczuk 2006; Massara and Schall 2004; McCann et al. 2012). However, there are few studies which are focused on integrating specific tools for teaching basic concepts in microbiology science and their application in environmental engineering focusing on unpredictable health risks. The pedagogical approach is necessary to reflect an innovative model for teaching practice that involves the health risk.

The purpose of this study is to highlight particular pedagogical tools for teaching a practical course that involves unpredictable health risk. It aims to describe a sequence within a broader experiment with a double perspective: microbiological and pedagogical, each with specific objectives.

a) From a **microbiological** point of view, the aim was to highlight the metabolic activity and multiplication of the yeast *Saccharomyces cerevisiae.* The transfer of the yeast to the optimal culture medium respected the aseptic working conditions. In addition, the degree of turbidity of the nutrient medium the yeast was placed in was measured.

b) From the **pedagogical** point of view the aim was to see to what extent the introduction of this practical course can increase students' academic performance in the field of microbiology associated with increasing knowledge on health and environmental risk.

Figure 1 presents sequences of the design and implementation of practical activities in order to understand how a modern and safe means of education was introduced and exploited. The following biological materials have been used for this study: *Saccharomyces cerevisiae* yeast culture, liquid culture medium optimal to yeast growth, 2% glucose solution. The following devices were used: Turbidity sensor (PS-2122), Pasco Scientific and a device for the preparation of glucose and yeast solution.

 Turbidity Sensor (PS-2122)	 Preparation of glucose and yeast solution in the MixToube
 Yeasts used in this experiment	 The yeast *Saccharomyces cerevisiae* laid on a nutrient medium

Figure 1 Exemplifying the design and implementation of microbiology practical activities with the help of specific teaching methods.

The exploited teaching strategy consists of *methods* of learning through discovery, problem-solving, exercise, conversation; *modern means* consisting of Turbidity Sensor (PS-2122) and MixToube and the frontal organizational form combined with individual measurements was an actional and interactive one. The educational *means* consisting only of Turbidity Sensor (PS-2122) and MixToube represent a modern approach which is different and superior in performance (both from a scientific and educational perspective) with respect to the instrumental structure consisting of a variety of tubes, one gas burner, seed pipettes, a thermostat, a microscope, Thoma blade.

Several issues considered essential both in scientific and especially in teaching terms are highlighted with regard to the didactic tools used during the practical course. We mention that the survey is based on several arguments which highlight the use of modern teaching means in practical activities:

- While the electronic learning means measured the multiplication of yeast in real time, the classical education means listed above could measure this process only in successive, shifted stages, with effects on both the evaluation accuracy and students' learning performance.
- If in the classical manner students needed two seminars (4 hours) in order to see the 5 phases of yeast multiplication and measure it, only one seminar (2 hours) is enough, when using this modern means, for the process to be fully observed and measured by the involvement of each student.
- When using traditional means of education there are major risks of measuring errors, significant environmental and health risks, as well as a lower degree of interaction among students, interest and level of involvement in the experiment, phenomena which get reverse connotations when working with modern means.

A further aspect to be taken into account is the need of ongoing evaluation of knowledge regarding environmental and health risks in microbiology laboratories.

Research methodology

The basis of this study is a quantitative methodology based on the use of an ameliorative and formative pedagogical experiment, aimed at demonstrating the positive effects of using SPARK turbidimeter Turbidity Sensor (PS-2122), Pasco Scientific as a modern teaching means in assimilating new microbiology knowledge associated with environmental and health risks.

The main research **hypothesis** is: does the use of the turbidimeter SPARK Turbidity Sensor (PS-2122), Pasco Scientific contribute to better results in the final assessment test, compared to the initial assessment test results regarding students' knowledge about environmental and health risks specific to practical activities?

The **objectives** of the experimental study are:

- pre-testing, which is the initial evaluation of the level of knowledge related to microbiology and knowing the environmental and health risks specific to practical activities;
- designing and implementing the practical activity by using modern teaching means;
- post-testing, which involves assessing the level of knowledge at the end of the activity.

The **research methods** which are used are the ameliorative and formative teaching experiment with pre and post knowledge assessment test, the analysis of activity products, observation, statistical and mathematical methods.

The group of participants consists of 15 second-year students studying in Biology at the Faculty of Science of "Vasile Alecsandri" University of Bacău.

To have their knowledge about microbiology general concepts assessed students responded to a test with 9 questions listed below:

1. Which are environmental and health risks specific to practical activities in the microbiology lab?
2. What is the culture medium used in the microbiology lab?
3. Which are the working conditions necessary to obtain a culture medium?
4. Does the activity of preparing and handling laboratory culture media involve environmental and health risks? Specify these risks.
5. What is the role of biological fluids’ turbidity?

6. Which are the methods of evaluating the turbidity of a biological fluid (culture medium)?
7. List the parameters which influence the turbidity of biological fluids (culture medium).
8. Describe one of the parameters with the highest environmental and health risk associated to the activity of measuring turbidity.
9. How can you explain the increasing of turbidity in a culture medium?

By voluntarily filling in this knowledge assessment test, students confirm that they were informed and were willing to participate in the research activities. The study complies with the international norms (*Declaration of Helsinki*) regarding the ethics in research which involves human subjects.

By the knowledge evaluation test, students could identify the environmental and health risks they may be exposed to while performing practical applications. For example, the risk of inhaling aerosols, contamination risk in the event of failing to obey the general protection rules (overalls, gloves), risk of environmental contamination by discharges of inappropriate products into the sewage or by other activities. After the practical application, the same assessment test was re-taken by students. Test responses before and after the lessons were compared from a statistical point of view. For this purpose, a questionnaire was applied to the same group of students before and after the lesson, to study the impact of interactive teaching on the accumulation of knowledge in the field of microbiology associated with increasing knowledge on health and environmental risk.

The practical course started with assessing the general microbiology knowledge (preparation and requirements of the culture medium used in the activities, applying the technique of seeding the culture media, sterilization concepts and rules, etc.). The operational objectives of the lesson and the research purpose were stated at the beginning of the practical course.

The nonparametric Wilcoxon test, also called rank test was used to process and compare the results of the initial assessment test to the ones after the practical course. This test, which is used for correlated data (paired samples), was chosen as response variables distributions scores are not distributed evenly. To have an estimation of the size effect (Field 2006), a parameter r was calculated on the basis of the given z-score. According to Cohen's criteria, the size effect is classified in relation to the values of parameter r as follows: small (values between 0.2 and 0.3), medium (values between 0.3 and 0.5), large (values between 0.5 and 0.7), and powerful (values higher than 0.7) (Field 2006).

Results and discussion

The results of the knowledge assessment test prior to (R_i) and after (R_f) the practical course (Figure 1) were statistically compared to quantify students' assessment in microbiology. According to the results, there is substantial progress in all aspects of the categories measured by the 9 items in order to determine the level of students' knowledge:

- specifying the environmental and health risks related to practical activities in the microbiology lab - a significant increase from an average of 8.47 to 9.93;
- identifying the characteristics registered by the culture medium used in the microbiology lab - a significant increase from an average of 7.87 to 9.6;
- establishing the working conditions necessary to obtain a culture medium - a significant increase from an average of 8 to 9.67;

- presenting environmental and health risks related to preparing and handling laboratory culture media - a significant increase from an average of 8.33 to 9.73;
- knowing the role of biological liquids turbidity - a significant increase from an average of 6.13 to 9.27;
- knowing the methods to assess the turbidity of the biological liquid (culture medium) - a significant increase from an average of 5.93 to 9.4;
- knowing the parameters which affect the turbidity of the biological fluid - a significant increase from an average of 4.47 to 9;
- describing one of the highest environmental and health risk parameters associated to the activity of measuring turbidity - a significant increase from an average of 5.47 to 9;
- explaining the increase of turbidity in a culture medium - a significant increase from an average of 5.33 to 9.67.

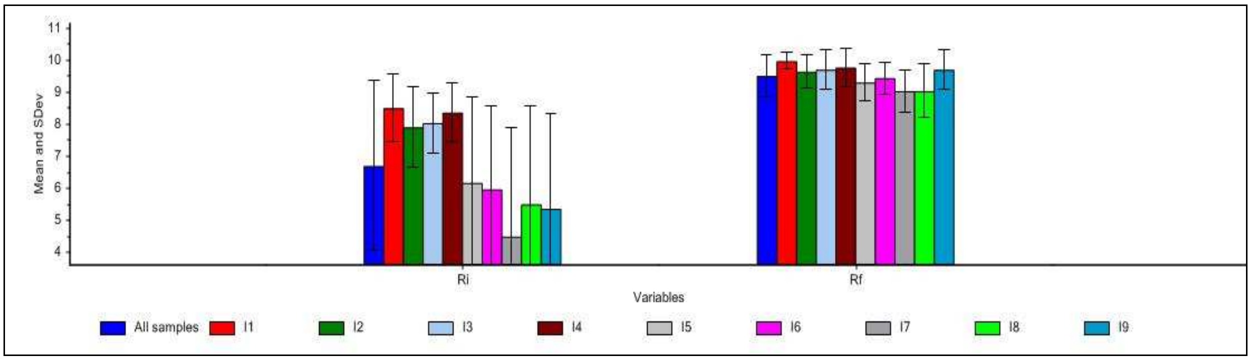

Figure 2. Graphic representation of the results of the knowledge assessment test prior to (R_i) and after (R_f) the practical course.

Table 1 indicates the statistical significance of the Wilcoxon test. The z-Score is -10.056 and has a significance of p = 0.000.

Table 1 Descriptive statistics (a), ranks (b) and test statistics (c) corresponding to Wilcoxon test.

a

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Ri	135	6.67	2.654	0	10
Rf	135	9.47	.656	8	10

b

Ranks

		N	Mean Rank	Sum of Ranks
Rf- Ri	Negative Ranks	0	0.00	0.00

	Positive Ranks	132	66.50	8778.00
	Ties	3		
	Total	135		

a. Rf < Ri
b. Rf > Ri
c. Rf = Ri

c

Test Statistics

	Rf - Ri
Z	-10.056
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

It is clear that the difference between the results of the knowledge assessment test before and after carrying out the practical course is statistically significant. The effect of this practical course with a high degree of interactivity on the acquisition of knowledge taught by microbiology was a strong one (r = 0.864).

The practical course is thus the key context to achieving significant knowledge (Martinez-Jimenez et al. 2009) under conditions of maximum risk reduction. The way how the double experiment described in this study (microbiology related and pedagogical experiment at the same time) was designed and conducted is original.

The first statistical results are those offered by the analysis of the results of the initial assessment test. The results of the first assessment test showed a reduced knowledge level related to the questions about the turbidity of biological fluids. In this context, students' participation in this practical course in microbiology is reasonable due to the way in which molecular phenomena in liquids can be easily highlighted with modern means. Students compared the classical and modern working methods used in the microbiology lab. At the same time, they could notice a reduced health and environmental risk, due to the use of modern teaching means. Turbidity is affected by the growth of yeasts in culture media. To monitor the yeast growth and development processes, conventional or modern methods can be used for the quantitative identification. In concrete terms, in the case when classical methods are applied for the quantitative identification of yeast, a longer time is necessary (from 1-2 h to 24 h), and also consumption of materials (e.g. the culture medium) and energy due to sterilization processes. In this situation, several stages are required along the experiment to highlight a metabolic issue.

The use of the SPARK turbidimeter Turbidity Sensor (PS-2122), Pasco Scientific, has facilitated students a rapid acquisition of new knowledge in maximum safety conditions related to health and environmental risks. In addition, the students were able to see the correlation of the turbidity of the culture medium where the yeast grew to the physiological phenomena of yeast multiplication and development. With the help of this sensor, the multiplication of yeast could be monitored every 10 minutes. Potential environmental and health risks they may be exposed to while performing practical applications were also identified.

Conclusions

The high level of interactivity provided by the use of modern teaching devices positively influenced the acquisition of knowledge taught by microbiology. The size effect generated by this way of teaching was a strong one (r = 0.864). Moreover, the use of modern means provided minimal environment and health risk. In this teaching method, the speed, clarity and precision with which metabolic aspects can be evaluated offers microbiology high attractiveness.

The analysis of the results on each item of the knowledge test contributes to highlight the students' progress in relation to microbiology concepts, but also to those concerning environmental and health risks, as a result of the effective integration of specific teaching methods in conducting practical activities. Results indicate clear progress of the students' level of knowledge for all environmental and health risk aspects measured by the 9 items. Significant progress was achieved in the following components: knowledge of the parameters that influence the turbidity of biological fluids; understanding the phenomena that cause the increase of the culture medium turbidity; description of the parameters with the highest environment and health risk associated to the practical activities of measuring turbidity.

This practical course taught by modern, interactive means facilitates the rapid acquisition of knowledge in the field of microbiology and is carried out under maximum work safety norms.

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