

BACTERIA AND YEASTS IN PRIMARY SCHOOL: A LABORATORY APPROACH TO THE STUDY OF MICROBIOLOGY AND BIOTECHNOLOGIES

Anna Lago^{1e}, Silvia Masiero^{2e}, Marta Bellio³, Elisabetta Piva⁴, Sophia Schumann⁵, Paola Irato⁶, Gianfranco Santovito^{7*}

¹Dr, University of Padova, ITALY, lagoanna92@gmail.com

²Dr., University of Padova, ITALY, silvia.masiero.6@studenti.unipd.it

³Dr, University of Padova, ITALY, marta.bellio@unipd.it

⁴Dr, University of Padova, ITALY, elisabetta.piva.2@studenti.unipd.it

⁵Dr, University of Padova, ITALY, sophia.schumann@studenti.unipd.it

⁶Dr, University of Padova, ITALY, paola.irato@unipd.it

⁷Prof, University of Padova, ITALY, gianfranco.santovito@studenti.unipd.it

*Corresponding Author

^eBoth authors contributed equally to this work

Abstract

The presented study compares two teaching and learning methodologies to improve the Biology curriculum in primary school. The presented study has two aims: 1) test whether youth exposed to microbiology and biotechnology improves the effectiveness of teaching, 2) underly the long-term outcomes of the implementation of an additional microbiology laboratory in the teaching curriculum, specifically its effect on youth motivation to learn. Nowadays, scientific evidence demonstrates that laboratory didactics have a stronger impact on lifelong learning than traditional didactic approaches, based on frontal lessons only. The epistemological and methodological structure is clear: Science, especially Biology, should not just be taught for its outcomes (concepts, theories, innovations,) but also, and especially, for its procedures leading to them. Therefore, laboratory activities, conducted through experimental methods, represent one of the best resources in order to develop problem-solving skills. In the scientific methods, every observation leads to a hypothesis and therefore, to new discoveries. In this way, youth gradually come to deepen their cognitive skills and better retain their scientific knowledge. The teacher's role is to avoid addressing questions by providing immediate explanations, instead it should provide guidance in postulating and verifying curiosity-driven hypotheses. By letting the children's curiosity guide the teaching activity, we demonstrate the capability to tailor the curriculum to the individual needs of the class, implementing a comprehensive training that includes aspects which are usually omitted by school programs, as they are considered too "far" from youth's actual cognitive ability. In this study, we presented youth's in primary schools with the opportunity to learn from the everyday used products of the biotechnological industry. In the presented methodology, we embrace children's interest for the microscopic world, and we expanded the syllabus to accommodate time to cover the topic of microbiology and its biotechnological applications in the food industry. We used bread and yogurt productions, as examples which allowed to introduce the topic of biotechnological applications using yeast (*Saccharomyces cerevisiae*) and bacteria (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*). The data collected, demonstrated that it was surprising for youth to "discover" that the dough of a bakery product and a dairy product is actually living materials. In conclusion, considering the outcomes of our research, it is evident that experimental teaching laboratories and a broadened science curriculum have outstanding educational implications on youth cognitive understanding of real-world phenomena, including the biotechnological processes underlying production of everyday food items.

Keywords: bacteria, life sciences, microbiology, primary school, scientific method, yeasts.

1 INTRODUCTION

In primary school and in the first cycle of education, Biology falls within the competence of general Sciences and, of course, it is unthinkable to deepen all its arguments, given the few available hours dedicated to this subject. However, it is possible to provide the students of a comprehensive view of this discipline. In pursuing this, it should get some significant milestones of Sciences in general, such as educating students to the scientific method. teaching the precision, working with hand and eye together in a coordinated manner mind, developing interdisciplinarity, breaking down the boundaries between one discipline and another (Alfieri et al., 1995; Longo, 1998).

In teaching Science, an appropriate framework for this purpose is the laboratory. The laboratory is a place where everything makes sense and it is an operational context for building not only Life Sciences knowledge, but also for developing the knowledge of other disciplines.

In the World and European scene, many studies analysed what are the most significant approaches to improve the learning of Sciences (Zandonella Necca et al., 2021; Barana et al., 2021; Bassi et al., 2021; Bertoncello et al., 2021; Frigerio et al., 2021; Furlan et al., 2021; Furlanetto et al., 2021; Pavan et al., 2021). Nevertheless, it was found that these practices are not used in the Italian school (Calvani, 2011).

This work consists of an experimental research based on the teaching and learning of Biology in a primary school (ten-year-old children). The main goal is to support the current scientific evidence that underlines the effectiveness of laboratory didactics. Moreover, we also aimed to prove that this method makes it possible to deal with several topics which are not currently mentioned in the Italian Guidelines of 2012 for primary school (Castoldi, 2011), but for secondary school.

Our didactic project revolved around a topic that is not frequently considered by primary school programs: microbiology and their biotechnology application. The obtained results proved that student interest in microscopic reality have a positive influence on their motivation to learn.

2 MATERIALS AND METHODS

2.1 The background and the Description of the Projects

The two educational experiences were conducted in two different school backgrounds, both located in the North-East of Italy, in the Veneto region.

The first project was carried out with sixteen 10-year-old students at the "Monte Grappa" primary school, in Galliera Veneta, Italy. It was developed around the approach of the biotechnology study of the fermentation of the yeast *Saccharomyces cerevisiae*.

Using three laboratory-experimental activities, pupils understood the biological yeast fermentation process. Moreover, they understood that:

- To make the bread dough "swell", it is necessary to use water, flour, and yeast.
- The yeast, a live organism, is the element that determines the "swelling" of the dough.
- The swelling of the dough corresponds to an increase of volume and not weight.

In addition, children studied the theme of the fermentation of the yeast *Saccharomyces cerevisiae* as an example of biotechnological process used by man for food production from very ancient times, and in many places of the world.

The second project was carried out with twenty-seven 10-year-old students at the "Vittorio Alfieri" primary school in Mirano, Italy. It was developed around the theme of the biotechnological application of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* bacteria, mainly responsible for the lactic fermentation process in the production of yogurt.

In the first phase of the project, we conducted two laboratory-experimental activities aimed at understanding the biochemical process of lactic fermentation. In addition, by observing the density of the yoghurt, we studied the effect of an acid in the milk. In the second phase, we conducted two other experiments to verify the presence of bacteria inside and outside the body, through Petri capsules that contained microorganisms from farm soil.

2.2 Lesson Models

We used two lesson models for the fulfilment of the projects:

The first was the lab. It was a sensory and practical educational format. By using it we lent a coherent structure to the lesson that was organized in three phases:

- 1) Experimental-observational phase: experiment fulfilment. The realization of the experiments followed the steps of the scientific method.
- 2) Individual verbalization phase: formulation of individual conceptions. While children were performing the experiments, we suggested that each student should reflect of their lab experience.
- 3) Collective discussion and final conceptualization phase: peer comparison and restructuring of personal ideas. After students built their own mental representations, there was a moment of collective discussion. This allowed shared ideas to increase knowledge and to elaborate on definitive learning.

The second was the frontal lesson. Some topics needed to be deepened by oral explanations from the teacher, so we decided to alternate frontal lessons with laboratory experiences. However, we tried to make this format of lessons as interactive as possible, avoiding whenever possible one-way communication (from teacher to pupil).





2.3 Activities





The fulfilment of activities is summarized in Table 1.



Table 1. Fulfilment of activities

YEASTS		
PHASE OF PROJECT	ACTIVITY	METHODOLOGY
Phase 1: survey of students' naive knowledge	<ul style="list-style-type: none"> • Macroscopic observation and handling of <i>Saccharomyces cerevisiae</i> yeast. • Class conversation (What is it? Why can we use it?) 	Class discussion
Phase 2: development of new learning	<ul style="list-style-type: none"> • Experiment 1 Hypothesis: Water, flour and yeast are needed in order to make the dough swell. <p>Students make 4 different doughs:</p> <ul style="list-style-type: none"> -dough a (water, flour, and yeast) -dough b (water, flour) -dough c (water, yeast) -dough d (flour, yeast) <p>Students observe that the first dough is the only one that swells.</p>	Scientific method
	<ul style="list-style-type: none"> • Experiment 2 Hypothesis: Yeast is the responsible of the swelling of the dough. <p>Students make 3 different doughs and in each one put a different quantity of yeast.</p> <ul style="list-style-type: none"> -dough a (1 spoon of yeast) -dough b (2 spoons of yeast) -dough c (3 spoons of yeast) <p>Students observe that the dough with a greater quantity of yeast swells</p>	



	<p>more than the other ones.</p> <ul style="list-style-type: none"> • Observation of the yeast through the microscope <p>Students realize that yeast is a unicellular organism.</p>  <ul style="list-style-type: none"> • Experiment 3 <p>Hypothesis 1: the swell of the dough implicates an increase of weight.</p> <p>Hypothesis 2: the swell of dough does not implicate an increase of weight because the weight of the ingredients is always the same.</p> <p>Students make 2 doughs with different quantities of ingredients. They weigh each one at the beginning and after the swelling.</p> <p>Students realize that the weight of each dough is not changed before and after the swelling.</p> 		
	<ul style="list-style-type: none"> • The concept cartoons <p>The aim of the concept cartoons is to introduce the alcoholic fermentation.</p>		<p>Frontal lesson</p>
<p>Phase 3. The fermentation as a biotechnological process</p>	<p>Students analyse the fermentation as an example of biotechnological process.</p>		
<p>Phase 4. Historical and cultural excursus of the yeast fermentation</p>	<p>Students realize that fermentation is one of the oldest forms of biotechnology. In fact, there are proofs that testify the food use of fermentation, for example by the ancient Egyptian.</p> <p>Students also realize that fermentation is used all over the world in order to make food. They analyse the vast use of yeast in East (tempeh, miso, ...).</p> 		
	<p>BACTERIA</p>		

PHASE OF PROJECT	ACTIVITY	METHODOLOGY												
<p>Phase 1: <i>studying of the biotechnological applications of bacteria for lactic fermentation.</i></p>	<ul style="list-style-type: none"> Survey about known knowledge of pupils about lactic acid fermentation. Sensorial comparison between milk and yoghurt. Concept cartoon about lactose and lactic acid. Focus about yoghurt ingredients. <div style="display: flex; justify-content: space-around;">   </div>	<p>Class discussion and frontal lesson</p>												
	<ul style="list-style-type: none"> Experiment 1: Which ingredients/agents contribute to the transformation of milk in yoghurt? Formulation of six hypotheses: <table border="1" data-bbox="387 1003 1203 1294"> <thead> <tr> <th></th> <th>WHOLE MILK AND LACTOSE</th> <th>LIGHT MILK AND LACTOSE</th> <th>WHOLE MILK, WITHOUT LACTOSE</th> </tr> </thead> <tbody> <tr> <td>+YOGHURT (with bacteria)</td> <td>Hypothesis 1</td> <td>Hypothesis 3</td> <td>Hypothesis 5</td> </tr> <tr> <td>+BACTERIA (powder)</td> <td>Hypothesis 2</td> <td>Hypothesis 4</td> <td>Hypothesis 6</td> </tr> </tbody> </table> <p>Fulfillment of experiment 1.</p> <ul style="list-style-type: none"> Conclusions: for the lactic fermentation are necessary lactose and bacteria (verified hypothesis 1,2,3,4). 		WHOLE MILK AND LACTOSE	LIGHT MILK AND LACTOSE	WHOLE MILK, WITHOUT LACTOSE	+YOGHURT (with bacteria)	Hypothesis 1	Hypothesis 3	Hypothesis 5	+BACTERIA (powder)	Hypothesis 2	Hypothesis 4	Hypothesis 6	<p>Laboratory and scientific method</p>
	WHOLE MILK AND LACTOSE	LIGHT MILK AND LACTOSE	WHOLE MILK, WITHOUT LACTOSE											
+YOGHURT (with bacteria)	Hypothesis 1	Hypothesis 3	Hypothesis 5											
+BACTERIA (powder)	Hypothesis 2	Hypothesis 4	Hypothesis 6											
	<ul style="list-style-type: none"> Experiment 2: what is the effect of an acid in the milk? Fulfillment of the experiment 2. Conclusions: acid allows the curdling of the milk. Formalization of new knowledge through conceptual map. 													
<p>Phase 2: Studying of the presence of bacteria in the</p>	<ul style="list-style-type: none"> Brief discussions about the birth and development of yogurt as a food biotechnology. Short frontal lesson about using of Petri's capsule and cultivation terrains. 	<p>Frontal lesson, laboratory, and scientific method</p>												

<p>environment</p>	<ul style="list-style-type: none"> • Formulation of different hypothesis about the presence of bacteria in the environment. • Experiment 3: Study on the presence of bacteria in the environment by means of contamination of cultivation terrains.  <ul style="list-style-type: none"> • Experiment 4: study of the presence of bacteria in the air. 	
	<ul style="list-style-type: none"> • Naked eye and magnifying glass observation of developed  <p>bacterial colonies in cultivation terrains.</p> <p>Conclusions about experiment 3.</p> <ul style="list-style-type: none"> • Video about binary fission. • Lesson about biological and structural characteristics of the bacteria • Conclusions about experiment 4. <p>Formalization of new knowledge through conceptual map.</p>	<p>Frontal lesson, laboratory and scientific method</p>

3 RESULTS AND DISCUSSION

The last stage of the experimental research consists in a comparison between the “expected data” and the “observed data”. The result of this comparison reveals the achievement of both goals of this research. First of all, it proves the current scientific evidence that underlines the effectiveness of didactics laboratory. Secondly, it confirms that this method makes it possible to deal with several topics which are omitted by school programs. In fact, starting from students’ interests and making students the main characters can have a great impact on learning because each topic becomes significant.

3.1 The effectiveness of Didactics Laboratory

The effectiveness of didactics laboratory is clearly shown in the results that students have achieved during the semi-structured tests.

The Figure 1 describes the level of competence achieved by each student. The test questions were a total of twenty-two and the score of each level of competence has been divided as follows:

- Starting Level, from 0 to 12 correct answers
- Base Level, from 13 to 15 correct answers
- Medium Level, from 16 to 18 correct answers
- Advanced Level, from 19 to 22 correct answers

Looking at the Figure 1, it is clear that most of the students achieved the *Advanced Level*. This data is very interesting. It demonstrates the effectiveness of didactic laboratory and that laboratory activities, conducted through experimental methods, have a strong impact on learning.

The students can gradually formalize their knowledge using their problem-solving skills. Didactic laboratory has a positive impact also with student who have some learning difficulties (*Base Level*). In fact, it allows creating an inclusive experience in which everyone can take part because everyone can be aware of what he can do.

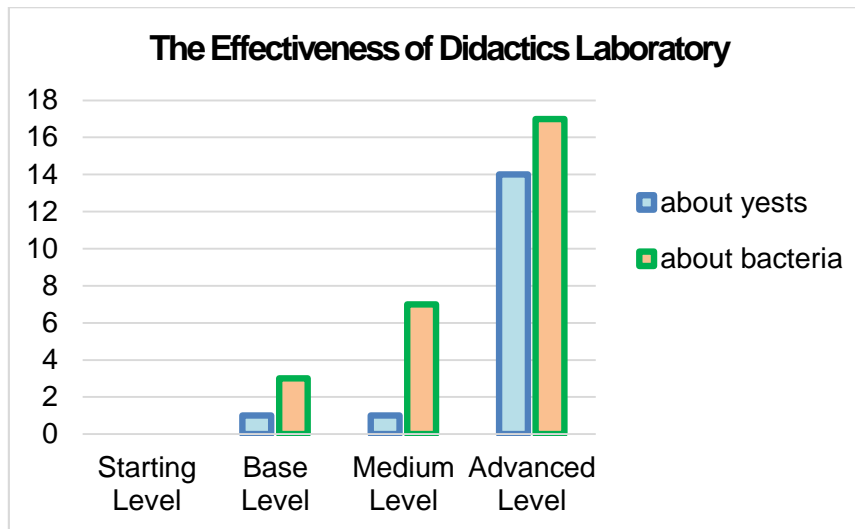


Figure 1. The effectiveness of didactics

3.2 The impact of Didactic Laboratories on Supporting the Motivation to Learn

The impact of didactic laboratories on supporting the motivation to learn is proved by the high appreciation that student have shown. Self-assessment requires students to reflect on their own work and to judge how well they have performed in order to identify their strengths, weaknesses, and areas that require improvement.

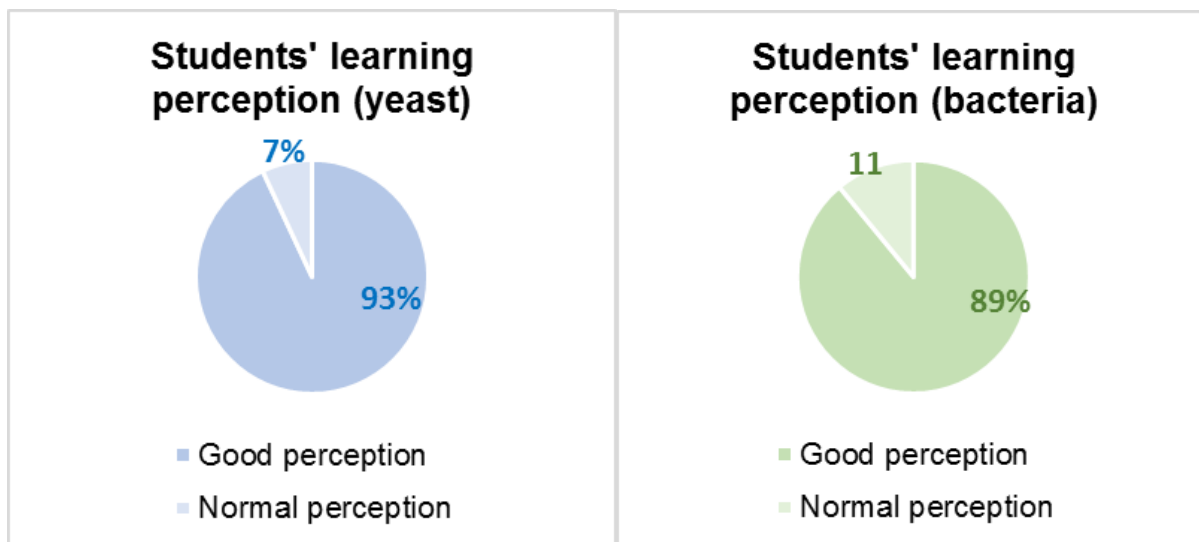


Figure 2. Students' learning perception

The graphic in Figure 2 describes the students' learning perception. Most of them have a good perception about their success. They thought they achieved a good competence level, and this data is confirmed by the tests' results.

4 CONCLUSIONS

Observing the results of our educational path, it appears that didactic laboratories and experimental methods are efficient for encouraging the learning processes. This method could really make a difference because it

allows actual real-life observation, asking personal questions and formulating hypothesis and, finally, finding answers. There is nothing better than "touching with hands" phenomena that surround us. This method also facilitates the inclusion of all pupils, in particular of the ones with special educational needs. All children, without exception, contributed to the co-construction of new knowledge, motivated by the research of answers coming from themselves.

Secondly, the results prove that this method makes it possible to deal with several topics which are not currently mentioned in the Italian Guidelines for primary school.

About the method, to find out some answers it would be necessary to go forward to a "didactic of doing," which consists in making real experiences of the theme debated (Santovito, 2015). This also means carrying out active teaching methods and offering learning opportunities through the laboratory. These methods require a great dedication for the organization of the experiences but promise a long and consolidated learning in a lifelong perspective. We also believe that it is essential to start from everyday life of pupils, from the phenomena of which they experience every day and, probably, take for granted. For example, for observing the results of biotechnological application of microorganisms such as yeasts and bacteria, it is just necessary to observe basic foods such as yoghurt, bread, cakes, wine, vinegar and many other ingredients easily found in the kitchen. The interest for the microscopic world should arise from its strangeness. Even though it is unseen, it affects considerably the existence of people, from many points of view. So, didactic proposals of this kind certainly should raise interest in pupils. Furthermore, they should promote the increase of scientific culture in children, who are the future citizens of tomorrow, with significant social-economic implications for our society.

REFERENCE LIST

- Alfieri, F., Arcà, M. & Guidoni, P. (1995) *Il senso di fare scienze. Un esempio di mediazione tra cultura e scuola.* Bollati Boringhieri, Torino.
- Barana, C., Dall'Acqua d'Industria, L., Bellio, M., Corrà, F., Bonato, M., Schumann, S., Irato, P. & Santovito, G. (2021) "Teacher, may we touch it?" An innovative laboratory approach to address macroscopic and microscopic anatomy of the digestive system of human and mammals in primary school. In: *INTED2021 Proceedings*, IATED, Valencia, <https://doi.org/10.21125/inted.2021.0210>
- Bassi, C., Fattori, G., Bellio, M., Corrà, F., Bonato, M., Schumann, S., Irato, P. & Santovito, G. (2021) Feel with the skin. A didactic research to introduce the integumentary system and sensory perception in primary school. In: *EDULEARN21 Proceedings*, IATED, Valencia. <https://doi.org/10.21125/edulearn.2021.1352>
- Bertoncello, O., De Rosso, A. & Santovito, G. (2021) My classroom as big as the world of CAITPR. An innovative educational-didactic approach for the training of eco-sensitive citizens. In: *EDULEARN21 Proceedings*, IATED, Valencia. <https://doi.org/10.21125/edulearn.2021.0372>
- Calvani, A. (2011) *Principi dell'istruzione e strategie per insegnare: Criteri per una didattica efficace.* Carrocci, Roma.
- Castoldi, M. (2011) *Progettare per competenze: Percorsi e strumenti.* Carocci, Roma.
- Frigerio, R., Bellio, M., Bonato, M., Santovito, G. & Irato, P. (2021) Fruit and vegetables: discovering conscious food choices. Creation of an educational project to stimulate the study of science in a class ii of a lower secondary school. In: *EDULEARN21 Proceedings*, IATED, Valencia. <https://doi.org/10.21125/edulearn.2021.1329>
- Furlan S., Bellio M., Corrà F., Bonato M., Schumann S., Irato P., Tamino G., Santovito G. (2021) A, B, C, D... NA: Genetics explained to children. an innovative didactic and laboratory proposal in primary school. In: *EDULEARN21 Proceedings*, IATED, Valencia. <https://doi.org/10.21125/edulearn.2021.1216>
- Furlanetto, L., Bellio, M., Corrà, F., Bonato, M., Schumann, S., Irato, P. & Santovito G. (2021) The circle of life. Human reproduction and embryonic development in primary school. In: *INTED2021 Proceedings*, IATED, Valencia, <https://doi.org/10.21125/inted.2021.0209>
- Gainotti, A. & Modelli, A. (2008) *Scienze della natura.* Zanichelli, Bologna.

- Longo, C. (1998). *Didattica della biologia*. La Nuova Italia Editrice, Firenze.
- Pavan, C., Bellio, M., Corrà, F., Bonato, M., Schumann, S., Irato, P. & Santovito, G. (2021) Microorganisms in the alimentation in primary school: the laboratory didactics in the teaching - learning processes of life sciences. In: *INTCESS2021 Proceedings*, OCERINT, Istanbul.
<https://doi.org/10.51508/intcess.202176>
- Santovito, G. (2015) *Insegnare la biologia ai bambini. Dalla scuola dell'infanzia al primo ciclo d'istruzione*. Carocci, Roma.
- Zandonella Necca, I., Bellio, M., Corrà, F., Bonato, M., Schumann, S., Irato, P., Tamino, G. & Santovito, G. (2021) Sustainable food: an innovative approach based on the assessment for learning method in secondary schools. In: *INTCESS2021 Proceedings*, OCERINT, Istanbul,
<https://doi.org/10.51508/intcess.202177>