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

Anna Lago, Silvia Masiero, Simone Bramuzzo, Erica Callegaro, Elena Poloni, Francesca Corrà, Gianfranco Santovito

Department of Biology, University of Padova (ITALY)

Abstract

The present work consists in an experimental research based on teaching and learning Biology in primary school. The aims of this research are two. First, it wants to support the current scientific evidence that underlines the effectiveness of laboratory didactics. Secondly, it aims to prove that this method makes it possible to deal with several topics which are not currently mentioned in the Italian Guidelines. Nowadays, scientific evidence demonstrates that laboratory didactics has 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 their products (concepts, theories, innovations,) but also, and especially, for their processes. Therefore, laboratory activities, conducted through experimental methods, represent one of the best resources in order to develop problem-solving skills, which underline a scientific mind. In the laboratory, every question or curiosity opens to new discoveries. In this way students gradually come to formalize their scientific knowledge. The teacher's role is to suspend his immediate explanation. He should be able to support spontaneous questions by students and the possibility to make hypothesis based on their naive theories. Starting from children's curiosity, it also makes possible to consider aspects that really intrigue them but which are usually omitted by school programs, as they are considered too "far" from pupils' actual cognitive ability. Children, unlike adults, do not tend to take anything for granted and are fascinated and intrigued by everything is around them, regardless of its hypothetical complexity. For this reason, teaching Biology in this way means to support students' intrinsic motivation, giving them not only scientific notions, but also concrete answers with practical implications in their daily lives. In this research, we followed children's interest for the microscopic world and we treated microbiology and its biotechnological applications in food industry. We started from bread and yogurt productions, which are very close to students' reality, in order to introduce the topic of biotechnological applications using yeast (*Saccharomyces cerevisiae*) and bacteria (*Streptococcus termophilus* and *Lactobacillus bulgaricus*). It was surprising for children to "discover" that the dough of a bakery product or a dairy product is actually a living material. As a matter of fact, the billion cells of living microorganisms, the yeasts and the bacteria, are in fact the protagonists of fermentation processes. In conclusion, considering the outcomes of our research, it is clear that the educational implications of laboratory didactics are very significant and therefore not negligible. Moreover, this work would be an exhortation to teachers to use this method and to become a potential changing agent.

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

1 INTRODUCTION

Biology is a discipline which has some specific characteristics that differentiate it from the others about subject matter, method of inquiry, used language and raised questions. Biology gives a lot of importance to description, it uses the contribution of various areas and it has an eminently historical character: all factors of originality with respect to other sciences.

In primary school and in the first cycle of education, Biology falls within the competence of general Sciences and, of course, it's unthinkable to deepen all its arguments, given the few available hours to this teaching. 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; teach the precision; "to work together in a coordinated manner mind, hand and eye" [1]; develop interdisciplinary breaking down the boundaries between one discipline and another. How precise Longo, "these objectives" training "can be achieved in various ways, but all have a common character: the lectures that [...] in this case must be integrated with other

ISBN: 978-84-617-8491-2

activities. The participation of the students should be more active. They must themselves to observe and to experience” [1].

In teaching Science, an appropriate framework for this purpose is the laboratory. The laboratory is a place where everything makes sense and it’s an operational context in which build not only Life Sciences knowledge, but also develop the knowledge of other disciplines. The laboratory, as explained by C. Longo, is useful because it’s a space that offers the “opportunity to come into contact with reality” [1] and that “not only will you see and touch, but also it acts” and “you can group to create an embryo of scientific method”. [1] In fact, “scientific knowledge [...] are the product of a long, thorough, repeated critical examination or, in other words, are the product of the scientific method” [1] and, therefore, in teaching Science and Biology reference to it is inevitable.

In the World and European scene, many studies analysed what are the most significant approaches to improve the learning [3-10]. Nevertheless, it was found that these practices aren’t used in the Italian school [11].

1.1 Purpose of the Research

This work consists of experimental research based on the teaching and learning of Biology in a primary school (ten-year-old children). The main goal is 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 [12], but for secondary school.

Starting from students’ interests had a great impact on supporting motivation to learn because it allowed each topic to be significant. In this way, it was also possible to introduce contents that omitted by school programs because it was considered too “far” from pupils’ actual cognitive ability.

Our didactic project considered a topic that is not frequently considered by primary school programs: microbiology and the biotechnology application. It proved that student interest in microscopic reality had a positive influence on motivation to learn. This motivation was also supported by the fact that didactics laboratory made them the real main characters of the production of knowledge. Before, teachers gave information for students to know and they were not questioned. Now, pupils could co-build knowledge thanks to an interactive process of co-construction.

2 MATERIALS AND METHODS

2.1 The competency model

In recent years, the concept of competence has become the innovation parameter of educational policies that the EU Member States have chosen to take [13].

The main attributes that characterize the concept of competence in operational sense are:

- Using personal knowledge to solve problematic situations about school and life because the competence is indissolubly connected with the action.
- Enlivening the personal internal resources, which should be "orchestrated" under a holistic vision, which does not consider them as a sum of individual parts, but as a set of elements in mutual interconnection.
- Knowing how to use external resources, that might materialize in tools, resources, and potentialities and actors involved, so in a situated knowledge about the context in which children are learning.

We decided to carry out our projects according to the competency model because it is student centred. Educational experiences of this type become finalized to the training of the student of today, who tomorrow will become citizen. Ultimately, we go from a perspective of knowing target knowledge (inert and abstract) to a knowledge aimed at performance (context knowledge). The student will interact with the knowledge society in a lifelong learning perspective. The learning process will no longer be restricted to the walls of the school building. Instead, it's a learning that continues even outside in a horizontal and vertical learning perspective. Promoting the process of learning as compared to focusing on the content to be learned implied school becoming one of learning and not just teaching.

2.2 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 region of Veneto.

The first project was carried out with sixteen 10-year old students at the primary school "Montegrappa", in Galliera Veneta. It was developed around the approach of the biotechnology study of the fermentation of the yeast Saccharomyces cerevisiae. The Table 1 shows the competence, the goal of competence, the learning objectives and the contents identified according to the competence model.

Table 1. Project 1

Identified competence [13]: basic competence in science and technology
Competence goal: obtaining a simple model of biotechnological process for food, utilizing the yeast *S. cerevisiae* (fermentation).
Learning objectives: -Recognize the fermentation as a biological process that involves yeast. -Know that the fermentation produces CO_2 after the demolition of reaction of sugars. -Know that fermentation is an example of a biological process aimed at creating products used by humans for food production.
Contents: -The yeast *S. cerevisiae* -The biological process of fermentation -Biotechnology in the food field (historical and intercultural overview of the fermentation process)

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

- So that the bread dough would “swell”, it needs 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 primary school "V. Alfieri" in Mirano. 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. Table 2 shows the identified competence, the goal of competence, the learning objectives and the content identified according to the competence model.

Table 2. Project 2

Identified competence [12]: basic competence in science and technology.
Competence goals [14]: -The student becomes interested about [...] the use of science in the field of scientific and technological development. -The student realizes of the complexity of the living system.
Learning objectives: -Recognize the lactic fermentation as a biological process, that involves bacteria. -Recognize the use of lactic fermentation as a biotechnological application aimed at the production of yoghurt. -Create experiences such as, for example: [...] the upbringing of microorganisms [5]. -Know the main structural and biological characteristics of the bacteria and their existence in the environment.
Contents: -The experimental method -The biological process of lactic fermentation -Effect of an acid in the milk -Historical review on yoghurt (ancient form of biotechnology)

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 for verifying the presence of bacteria inside and outside the body, through Petri capsules that brought in microorganisms from farm terrain.

2.3 Lesson models

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

The first and main used was the lab. It was a sensory and practical educational format. By using it we lent a coherent structure to the lesson respective to an inductive approach, organized in three phases:

1. Experimental-observational phase: experiment fulfilment. The realization of the experiments followed the steps of the scientific method. The students, step by step, were encouraged to ask questions about a certain phenomenon. The teacher asked some incentive questions of the students who discovered many possible ways for answering the questions (hypotheses formulation). Later, children expressed the ways that it would be possible to verify their hypothesis. The students then performed the experiments together and fulfilled their experimental experience.
2. Individual verbalization phase: formulation of individual conceptions. While children were performing the experiments, we suggested that each student create a reflection of their lab experience. By using some semi-structured forms, each child reflected on what he or she was looking at. Consequently, their cognitive structures started to change.
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 is 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).

2.4 Activities

The fulfilment of activities is summarized in Table 3.

Table 3. Fulfilment of activities

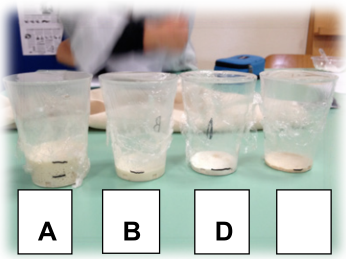
<table>
<tr><th colspan="3">YEASTS</th></tr>
<tr><th>PHASE OF PROJECT</th><th>ACTIVITY</th><th>METHODOLOGY</th></tr>
<tr><td>Phase 1: survey of students' naive knowledge</td><td>• Macroscopic observation and handling of Sacchoromyces cerevisiae yeast.
• Class conversation (What is it? Why can we use it?, …)</td><td>Class discussion</td></tr>
<tr><td rowspan="3">Phase 2: development of new learning</td><td>• Experiment 1
Hypothesis: Water, flour and yeast are needed in order to make the dough swell.
Students make 4 different dough:
-dough a (water, flour and yeast)
-dough b (water, flour)
-dough c (water, yeast)
-dough d (flour, yeast)
Students observe that the first dough is the only one that swells.


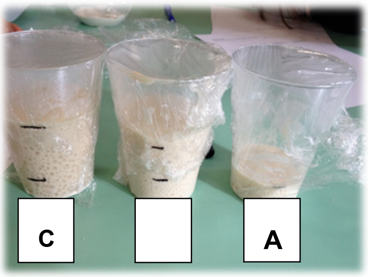
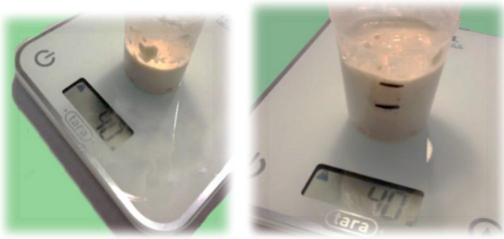
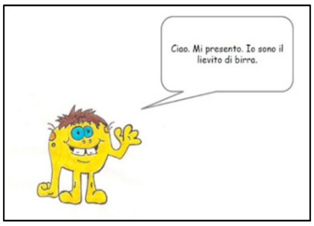
Fig. 1. Dough A is the only dough that swells.</td><td rowspan="3">Scientific method</td></tr>
<tr><td>• Experiment 2
Hypothesis: Yeast is the responsible of the swelling of the dough.
Students make 3 different doughs and in each one put a different quantity of yeast.
-dough a (1 spoon of yeast)
-dough b (2 spoons of yeast)
-dough c (3 spoons of yeast)
Students observe that the dough with a greater quantity of yeast swells more than the others ones.


Fig. 2. Dough c swells more than the others ones because in it there is the greater quantity of yeast.</td></tr>
<tr><td>• Observation of the yeast through the microscope
Students realize that yeast is pluri-cellular organism so it is a living being.</td></tr>
</table>

	 *Fig. 3. Students use the microscope to observe the cells of the yeast.*	
	• Experiment 3 Hypothesis 1: the swell of the dough implicates an increase of weight. Hypothesis 2: the swell of dough doesn't implicate an increase of weight because the weight of ingredients is always the same. Students make 2 doughs with different quantities of ingredients. They weigh each one at the beginning and after the swelling. Students realize that the weight of each dough is not changed before and after the swelling.  *Fig. 4. The weight before the swelling and the weight after the swelling.*	
	• The concept cartoon The aim of the concept cartoon is to introduce the alcoholic fermentation.  *Fig. 5. A scene of the concept cartoon.*	Frontal lesson
Phase 3. The fermentation as a biotechnological process	Students analyse the fermentation as an example of biotechnological process.	
Phase 4. Historical and cultural excursus of the yeast fermentation	Students realize that fermentation is one of the oldest form of biotechnology. In fact, there are proofs that testify the food use of fermentation, for example between Egyptian. 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, …).  *Fig. 6 Students make the tempeh.*	

<table>
<tr><td></td><td>BACTERIA</td><td></td></tr>
<tr><td>PHASE OF PROJECT</td><td>ACTIVITY</td><td>METHODOLOGY</td></tr>
<tr><td>Phase 1: studying of the biotechnological applications of bacteria for lactic fermentation.</td><td>

- 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.

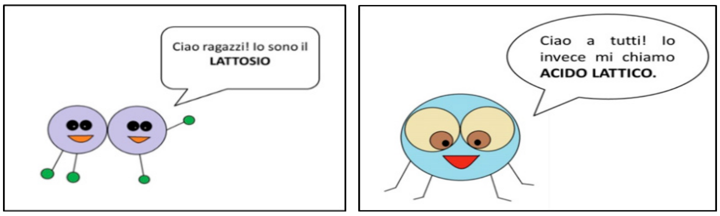


Fig. 7 Concept cartoon about Lactose and Lactic Acid
</td><td>Class discussion and frontal lesson</td></tr>
<tr><td></td><td>

- Experiment 1: Which ingredients/agents contribute to the transformation of milk in yoghurt?
- Formulation of six hypotheses:

<table>
<tr><td></td><td>WHOLE MILK AND LACTOSE</td><td>LIGHT MILK AND LACTOSE</td><td>WHOLE MILK, WITHOUT LACTOSE</td></tr>
<tr><td>+YOGHURT (with bacteria)</td><td>Hypothesis 1</td><td>Hypothesis 3</td><td>Hypothesis 5</td></tr>
<tr><td>+(powder) BACTERIA</td><td>Hypothesis 2</td><td>Hypothesis 4</td><td>Hypothesis 6</td></tr>
</table>

Fig. 8. Fulfilment of experiment 1

- Fulfilment of experiment 1.
- Conclusions: for the lactic fermentation are necessary lactose and bacteria (verified hypothesis 1,2,3,4).
</td><td>Laboratory and scientific method</td></tr>
<tr><td></td><td>

- Experiment 2: what is the effect of an acid in the milk?
- Fulfillment of the experiment 2.
- Conclusions: acid allows the curding of the milk.
- Formalization of new knowledge through conceptual map.

Fig. 9. Thickened milk obtained for merit of citric acid and acetic acid
</td><td></td></tr>
</table>

<table>
<tr>
<td>Phase 2:

Studying of the presence of bacteria in the environment</td>
<td>

- 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.
- Formulation of different hypothesis about the presence of bacteria in the environment.
- Experiment 3: Study of the presence of bacteria in the environment by means of contamination of cultivation terrains.
- Experiment 4: study of the presence of bacteria in the air.

Fig. 10. Fulfilment of experiment 3

</td>
<td>Frontal lesson, laboratory and scientific method</td>
</tr>
<tr>
<td></td>
<td>

- Naked eye and magnifying glass observation of developed bacterial colonies in cultivation terrains.

Fig. 11. Observation of the results obtained in the experiment 3.

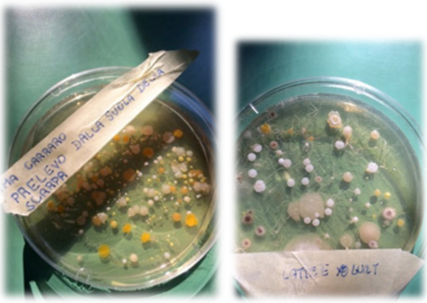


Fig. 12. Examples of bacterial colonies proliferated on cultivation terrains.

- Conclusions about experiment 3.
- Video about binary fission.
- Lesson about biological and structural characteristics of the bacteria
- Conclusions about experiment 4.

Formalization of new knowledge through conceptual map.

</td>
<td>Frontal lesson, laboratory and scientific method</td>
</tr>
</table>

2.5 Assessment

In both projects, we decided to present a semi-structured test to students. It consisted of: a series of objective questions, such as true/false, to completion and multiple choice questions. We decided to adopt this kind of test because it allows students to minimize ambiguity and makes sure that the result is accepted with confidence by the pupil [15]. This was also done because of the absence of subjectivity from the teacher.

3 RESULTS AND DISCUSSION

The last stage of the experimental research consists in a comparison between the "awaited data" and the "observed data". The result of this comparison reveals the achievement of both aims of this research. First of all, it proves the current scientific evidence that underlines the effectiveness of didactics laboratory. Secondly, this method makes it possible to deal with several topics which are omitted by school programs. In fact, starting from students' interests and making student the main characters have a great impact on supporting to learn because it allows making each topic significant.

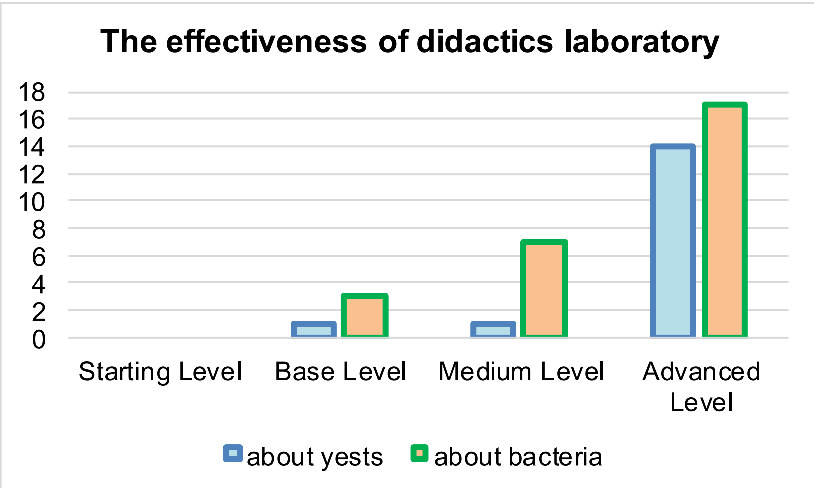


Figure 13 The effectiveness of didactics laboratory

3.1 The effectiveness of didactics laboratory

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

The Figure 13 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:

Level of competence	Correct answers
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 the Figure 13, both researches prove that most of the students achieved the *Advanced Level*. This data is very interesting. It demonstrates the effectiveness of didactic laboratory. 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 of it because everyone can make available what he can do.

3.2 The impact of didactics laboratory on supporting the motivation to learn

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

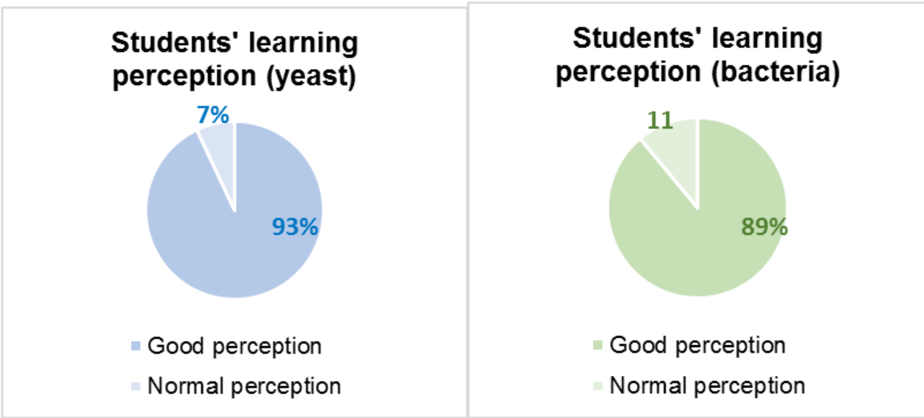


Figure 14 Students' learning perception

The graphic (Fig. 14) 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 paths, it appears that didactics laboratory 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, finally, finding answers. For us 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, motived 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 "didactics of doing," which consists in making real experiences of the theme debated [16]. This also means carrying out active teaching methods and offering learning opportunities through the laboratory. These methods require a great dedication in the organization but promise a long and consolidated learning in a lifelong learning 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's just necessary to observe basic foods such as yoghurt, bread, cakes, wine, vinegar and many others. The interest to 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 future citizens of tomorrow, with significant social-economic implications for our society.

REFERENCES

[1] C. Longo, "Didattica della biologia". Scandicci: La Nuova Italia, 1998.

[2] F. Alfieri, M. Arcà, P. Guidoni. "Il senso di fare scienze. Un esempio di mediazione tra cultura e scuola". Torino: Bollati Boringhieri, 1995.

[3] A. Gaiotto, S. Tonon, G. Santovito. "The scientific method in the teaching of life sciences in primary school. The plants and their seasonal changes". In EDULEARN13 Proceedings of the 5th International Conference on Education and New Learning Technologies; Valencia: IATED, pp. 4226-4235, 2013.

[4] S. Tonon, A. Gaiotto, G. Santovito. “The active teaching of life sciences in primary school: a comparative approach to the musculoskeletal system”. In EDULEARN13 Proceedings of the 5th International Conference on Education and New Learning Technologies; Valencia: IATED, pp. 4289-4298, 2013.

[5] C. Pavan, G. Santovito. “The laboratory didactics in the teaching -learning processes of life sciences. an educational project on microorganisms in the alimentation in primary school”. In EDULEARN14 Proceedings of the 6th International Conference on Education and New Learning Technologies; Valencia: IATED, pp. 7546-7555, 2014.

[6] I. Zandonella Necca, G. Tamino, G. Santovito. “Sustainable food: an educational proposal, for key stage 3 in secondary schools, based on the assessment for learning method”. In EDULEARN14 Proceedings of the 6th International Conference on Education and New Learning Technologies; Valencia: IATED, pp. 7348-7356, 2014.

[7] V. Toninato, G. Santovito. “The laboratory didactics in the teaching-learning processes of life sciences. An educational project on the structure of the flower and the inflorescences phenomenon in primary school”. In EDULEARN15 Proceedings of the 7th International Conference on Education and New Learning Technologies, Barcelona; Valencia: IATED, pp. 2245-2254, 2015.

[8] T. Trevisan, G. Santovito. “Teaching evolution: a laboratory approach”. In EDULEARN15 Proceedings of the 7th International Conference on Education and New Learning Technologies; Valencia: IATED, pp. 2234-2244, 2015.

[9] A. Gaiotto, G. Santovito. “An innovative didactic approach to the study of invertebrate animals in primary school”. In EDULEARN16 Proceedings of the 8th International Conference on Education and New Learning Technologies; Valencia: IATED, pp. 1410-1418, 2016.

[10] E. Rossi, G. Santovito. “Introduction to Mendelian genetics in primary school”. In EDULEARN16, Proceedings of the 8th International Conference on Education and New Learning Technologies; Valencia: IATED, pp. 1374-1382, 2016.

[11] A. Calvani, “Principi dell’istruzione e strategie per insegnare: Criteri per una didattica efficace”. Roma: Carrocci, 2011.

[12] AA. VV., “Indicazioni nazionali per il curricolo della scuola dell’infanzia e del primo ciclo di istruzione”, Roma: Ministero dell’Istruzione, dell’Università e della Ricerca, 2012.

[13] AA. VV., “Raccomandazione del Parlamento europeo e del Consiglio, del 18 dicembre 2006 , relativa a competenze chiave per l'apprendimento permanente”, Gazzetta ufficiale dell’Unione europea, 2006.

[14] M. Castoldi, “Progettare per competenze: Percorsi e strumenti”. Roma: Carrocci, 2011.

[15] M. Castoldi, “Valutare per Competenze”. Roma: Carrocci, 2011.

[16] G. Santovito, “Insegnare la biologia ai bambini”. Roma: Carrocci, 2015.