The Microbiological@mind project: a public engagement initiative of Turin University bringing microbiology and health education into primary schools [* G.Banche is the corresponding author]

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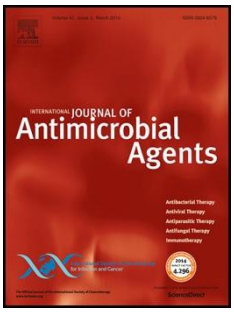

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The Microbiological@mind project: a public engagement initiative of Turin University bringing microbiology and health education into primary schools

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Running title: Microbiology education in primary schools to promote scientific knowledge and health-related issues

Highlights

- Public misunderstandings about microbes and antibiotics should be discouraged.
- Hands-on educational programs may help to take key scientific messages to students.
- The use of scientific web-based resources should be implemented across Italy.
- Early childhood microbial literacy may reinforce awareness on antibiotic use.

ABSTRACT

Despite ongoing global efforts, antimicrobial resistance continues to threaten the treatment of an ever-increasing range of bacterial infections. Substantial evidence has shown that public education programs that foster microbial literacy amongst young school audiences may improve correct knowledge of specific health issues, such as prevention of microbial infections and responsible use of antibiotics. The aim of the Microbiological@mind project was to engage primary school students with the subject of microbiology, to promote both scientific interest and awareness towards correct behaviors that may ensure a safer lifestyle. Interactive workshops based on a full ‘‘hands on’’ approach were carried out at primary schools of Turin by an expert team from the University of Turin to over 1200 children aged 9-11 years. A questionnaire (pre- and post-activity test) on the main topic (i.e.antibiotics) was used to assess project effectiveness. The workshops provided a useful means to strengthen the understanding of basic microbiology concepts amongst students. Students’ baseline knowledge of antibiotics was quite low, as low percentages of correct answers on antibiotic action and use (5.0% and 12.1%,respectively) were found in the pre-activity tests. A significant increase (p<0.0001) in correct knowledge was observed in the post-activity tests, after implementation of the teaching activity. Our findings support the idea that microbial literacy in early childhood through the use of hands-on educational programs is of great importance to foster children’s interest in science learning and to provide young people with general and specific health-related issues, such as the prudent antibiotic use, for a more responsible citizenship.

Keywords: microbiology, health education, antimicrobial resistance, public engagement activities

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1. Introduction

Nowadays, the spread of antimicrobial resistance (AMR) within pathogenic microorganisms represents a seriously alarming threat to global public health, leading to prolonged hospital stays, treatment failures, and increased healthcare costs [1,2]. In Europe, many efforts have been put into educational programs aimed at prescribers and healthcare professionals to optimize antimicrobial therapy and reduce antimicrobial resistance. Many reports have consistently documented that these interventions are fairly effective in reducing antibiotic overuse [3,4]. However, results from the last 2016 Eurobarometer survey, as well as from a cross-sectional study recently conducted in Italy, have shown that many adults still have serious misunderstandings about antibiotics and that children's basic knowledge of antibiotic use is poor [5,6]. Thus, in the past few years, a variety of educational campaigns, such as the "European Antibiotic Awareness Day" led by the European Centre for Disease Prevention and Control, and many other programs have been proposed to improve global awareness of AMR in general public, including school-aged children [7,8].

In Europe, the e-Bug project, which was developed in 2006, partly funded by the European Commission (DG SANCO), is a representative online education resource that aims to improve young people's understanding of the importance of hygiene and responsible antibiotic use. Currently e-Bug is led by the Public Health England's Primary Care Unit in England and involves a consortium of 26 international partner countries [8]. In Italy, the Istituto Superiore di Sanità (ISS) is the current e-Bug partner, being directly involved in public health protection [9,10].

In this context, we report the experience of a public engagement initiative promoted by the University of Turin and funded by the Italian Ministry of Education University and Research

(MIUR), entitled the *Microbiological@mind project*, targeted at primary school children. The main aim of the project was to educate children about microbiology, reinforcing awareness of positive behaviors (i.e. hand washing, proper antibiotic use) that may ensure a safer lifestyle. Furthermore, the project was in line with the European Community programs focused on extending science education into primary schools to foster interest in science starting from childhood [11].

In addition, this initiative aimed at strengthening the relationship between the university and the primary schools in the surrounding territory.

2. Materials and methods

2.1. Project description and participants

The project started on September 2011, and through 2011-2012, 2013-2014 and 2014-2015 school years, scientific workshops were carried out at 26 different primary schools of Turin by an expert team from the Department of Public Health and Pediatrics, University of Turin, to a large target audience of over 1200 children aged 9-11 years. Schools that had not already planned microbiology lessons were asked to participate in this project by e-mail, telephone and letter.

The data analysis of the project was concluded on March 2016.

2.2. Methodological approach

The project combined educational aspects with playful activities and took various forms: "hands-on" experiments, microscope observation, quizzes, interactive games and team competitions.

The scientific workshops were divided into two distinct two-hour sessions per class, spaced 4-6 weeks in time to enable students to rework content and experiences. A take-home booklet was printed and distributed to all participants, giving the opportunity to include personal notes and statements.

2.3. *Planned activities*

During the scientific workshops five main topics were presented: 1) introduction to microbes; 2) spread of infection; 3) the body's natural defences; 4) treatment of infection; and 5) prevention of

infection. The workshop activities related to each main topic are described in detail in Table 1. Overall, the educational content and the key learning outcomes were similar to those proposed by the junior pack of the e-Bug website.

2.4. Project evaluation and dissemination

To evaluate the project effectiveness and the knowledge change after the teaching activity, pre- and post-activity questionnaires focused on the main topic (i.e. treatment of infection) were administered to students. Students were required to complete identical questionnaires at two different timepoints: one week before the first workshop and immediately after the second workshop. Generally, there was at least a six-week time interval between pre and post-activity tests. Students were asked to tick either yes or no to a simple series of statements. Teachers in every school were instructed on how to complete the questionnaires. As students were minors, parental consent was obtained.

The dissemination of the results was pursued via: informal meetings with school teachers, conferences, and publications [12].

2.5. Data analysis

All the questionnaires were processed anonymously. Only data from students who filled in all two questionnaires were analyzed. All incorrectly completed questionnaires were excluded from data analysis. Data from pre- and post-activity tests were analyzed using GraphpadPrism 7 (Graphpad Software,San Diego,CA,USA). Associations between variables were analyzed with Chi-square test. A p value of <0.05 was considered significant.

3. Results and Discussion

Increasing awareness of prudent antibiotic use amongst prescribers as well as the general public is widely recognized as one of the cornerstones in tackling antimicrobial resistance. Across Europe, public scientific literacy about microbiology, hygiene and health education since childhood has been currently considered as one of the key strategies to accomplish this goal.

In Italy, although primary school curriculum covers the topic of human health and hygiene according to the Italian National Guidelines, limited information about microbes and prudent antibiotic use is currently provided within lower compulsory education [13]. Unlike many other European countries, the majority of Italian primary schools are not equipped well enough to offer scientific laboratory activities for their students, inasmuch as science teaching is generally more concentrated in lower and upper secondary compulsory schools. Moreover, teachers in Italian primary school are generalists and very few of them have a strong scientific background [11]. Therefore, in this context, the *Microbiological@mind project* was promoted to enrich the basic scientific curriculum in primary schools through a close collaboration between schools and university. This initiative was specifically targeted at primary school children, as a large body of research has suggested that these early years lay a powerful foundation for subsequent lifelong learning [14]. Moreover, the 9 –11 age group of students in fourth grade classes was considered the most appropriate at which to aim the project. In fact, children at this age have already learned a substantial amount about the natural world, and they possess reasoning processes that support causal inference and evidence interpretation [14]. Moreover, teaching children quite difficult microbiological concepts just before they leave primary school allows to sustain children's natural and spontaneous interest in scientific knowledge, avoiding mistakes and misconceptions.

Based on qualitative results from students' and teachers' interviews, this public engagement initiative was warmly welcomed in schools in Turin. As highlighted by school teachers involved in this project, the practical work, through simple fun activities was particularly effective in influencing student interest towards the microbiology subject addressed (Table 1). The hands-on teaching strategy provided in a formal classroom context was easily accepted. Through this approach, it was easy to motivate and interest young students, bringing scientific education and key learning concepts on microbiology closer to this young audience. Previous studies have shown that the use of interactive activities can greatly improve public knowledge on specific health issues such as microbial infections, antimicrobial resistance and prudent antibiotic use [7,15-17]. Furthermore,

the direct contact and dialogue of microbiologists, who offered all the participants their scientific knowledge and expertise with an exchange of questions and answers, were considered extremely successful either by young students or by the teachers.

Based on children's drawings (Figure 1), we observed that some children appear also to understand complex concepts about microorganisms, highlighting, as also previously reported in literature, that there is a clear mismatch between children's ability to comprehend these ideas and the curriculum content in primary school [18].

On the other hand, based on feedback from teachers' interviews, results showed that the online resources, such as the e-Bug website, are still poorly known and used in primary schools in Turin. In fact, only two teachers out of forty-eight interviewed (4.2%) had visited the e-Bug website in the past. These findings are in agreement with data from a recent report, showing that e-Bug web resources are still poorly visited in Italy (< 5% proportion of total visitors between September 2010 and August 2013) [19]. Hence, further efforts should be expended to implement the autonomous use of all useful scientific web-based resources, such as the e-Bug website, among Italian students and teachers.

In this study, 956 questionnaires (pre- and post-activity tests), out of all those returned by school teachers, were considered amenable for data analysis, with an overall true response rate of about 80%. Based on results from the questionnaires, lack of basic knowledge regarding antibiotics was detected among the majority of the young students. As reported in Table 2, low percentages of correct answers were found in the pre-test, with only 5.0 % and 12.1% of correct answers on antibiotic action and use, respectively. Significant increases in knowledge were observed in the post-test (about 6 weeks later), after implementation of the teaching activity. Knowledge of the correct use of antibiotics for bacteria rather than viruses and other microorganisms rose from 5.0% to 77.2% in the post-test (p<0.0001). Whereas, knowledge of the risk of bacterial resistance to antibiotics from their incorrect use rose from 12.1% to 73.6% in the post-test (p<0.0001).

Regarding the incorrect answer on antibiotic use for cold and flu treatment, a significance decrease

in choice of this option in the post-test was found (p<0.0001). Our positive findings on this topic are particularly important, considering that misconceptions about this specific notion, as a consequence of bacteria and viruses being considered as similar, can lead to subsequent incorrect attitudes and behaviors towards antibiotic use. Furthermore, many other recent reports emphasize that this misunderstanding about antibiotic use is far too common among both youngsters and adults, and, therefore, it should be strongly discouraged [4,6,7,15,16,20].

In conclusion, qualitative and quantitative results from this large-scale intervention, including a large number of schools from a Northwest region of Italy with little prior experience with such initiatives, seem encouraging. Nevertheless, the whole interpretation of these positive findings should take into account the potential limitation of the project design, which was not deliberately devised as a randomized controlled trial due to difficulties in recruiting control schools.

To sum up, although it is difficult to determine the true success of this project, due to the lack of data on long-term retention of knowledge and real behavior changes of students after being taught, data gathered support the idea that early childhood microbial literacy through a hands-on approach should contribute to engage students with scientific subjects and health-related issues.

In addition, these findings encourage the prospects of strengthening the scientific knowledge of the general public about microbial infections and prudent antibiotic use through a closer collaboration between compulsory schools and university, contributing to disseminate at a local level correct scientific and health information amongst the younger generation for a more responsible citizenship.

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Competing interests: None declared.

Ethical approval: Not required.

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Figure 1. Examples of children's drawings of microorganisms for different categories. A: viruses; B: bacteria; C: fungi. Many children consider that microorganisms look like small animals and drawings were frequently anthropomorphised.

269 **Table 1. Classroom planned activities and educational content**

TOPIC	ACTIVITIES	KEY LEARNING OUTCOMES
INTRODUCTION TO MICROBES	HARMFUL AND USEFUL MICROBES A large gallery of photographs of both useful and harmful microbes (bacteria, yeasts, fungi, and viruses) was projected. Students used these images as a basis to make drawings and/or models of microbes in Petri dishes using play dough (Figure 1). Children were taught about the microbial communities that normally exist throughout the human body. A simple *in vitro* experiment of the bread leavening process using baker's yeast (*Saccharomyces cerevisiae*) was carried out.	Microbes are everywhere and are invisible to the naked eye. They have different shapes and sizes. Some harmful microbes can make us ill. Many useful microbes exert beneficial relationships with the human body. Useful microbes also play a key role in food production.
SPREAD OF INFECTION	IMPORTANCE OF EVERYDAY HYGIENE Students were invited to collect different types of samples from skin (before and after hand washing with or without soap), from mouth (before and after teeth washing), and from classroom surfaces, using Petri dishes with different growth media, such as Nutrient agar (NA), Mannitol Salt agar (MSA), and Sabouraud Dextrose agar (SDA). NA and MSA plates were transferred to the university laboratory by the staff for further incubation. SDA plates were left into the classroom to allow students daily observation of fungal growth (environmental moulds). A macroscopic examination of the different colonies of either bacteria or fungi grown onto agar plates was carried out. The bacterial load of every student's hands before and after hand washing was observed. Gram-stained slides of bacteria (*Streptococcus spp*.; *Staphylococcus spp*.; *Lactobacillus spp*.; *Escherichia coli*) were viewed under a high power microscope placed in every classroom. Slides of yeasts (*Saccharomyces cerevisiae*) and moulds (*Penicillium spp*.; *Aspergillus spp*.) were also observed under the microscope.	Infection can be spread through direct physical contact between people, airborne droplets from coughing and sneezing or from contact with surfaces and objects. Close environments and inanimate objects serve as resting grounds for microbes. Contaminated hands are the primary mode of transmission of many infectious diseases, particularly among those living in close proximity to one another. Hand washing is the most effective way of reducing the spread of infections caused by harmful microbes.
THE BODY'S NATURAL DEFENCES	BLOOD CELLS AND THE IMMUNE SYSTEM A Diff-Quick stained blood smear was viewed under a high power microscope to help students identify the white blood cells that make up the body's immune system.	The human body has many natural defences to fight infection.
TREATMENT OF INFECTION	ANTIBIOTIC ACTION AND USE The discovery of antibiotics was explained to students, giving more information on the benefits of antimicrobial drugs against bacterial infections. Observation of different antibiograms was carried out, followed by expert-led discussion in the classroom.	An appropriate use of antibiotics helps to prevent the development of antibiotic-resistant bacteria and the resulting failure of antibacterial therapies.

PREVENTION OF INFECTION	VACCINES The discovery of vaccines was explained to students, giving more information about the importance of vaccinations in reinforcing the immune system since childhood. Different images of either bacteria or viruses which should be used as a vaccine were projected.	Vaccines introduce an unarmed version of a specific microbe (bacteria or virus) into the body, which help to teach the human body how to fight an infection. Vaccines help to prevent the spread of either bacterial or viral infections within a community.

274 **Table 2. Student's knowledge on antibiotics before and after interactive scientific workshops**

QUESTION 1: ANTIBIOTIC ACTION			
	Pre-test (total = 956 students) n (%)	**Post-test (total = 956 students) n (%)**	***p* value**
Correct statement: 1. Antibiotics are effective against bacteria	48 (5.0)	738 (77.2)	< 0.0001
Incorrect statements: 3. Antibiotics are effective against bacteria and viruses	725 (75.8)	122 (12.8)	< 0.0001
• Antibiotics are effective against all microorganisms (bacteria, viruses and fungi)	183 (19.1)	96 (10.0)	< 0.0001
QUESTION 2: ANTIBIOTIC USE			
	Pre-test (total = 956 students) n (%)	**Post-test (total = 956 students) n (%)**	***p* value**
Correct statement: 1. The unnecessary use of antibiotics can increase the resistance of bacteria to them	116 (12.1)	704 (73.6)	< 0.0001
Incorrect statement: 2. The use of antibiotics can speed up the recovery of cold, cough, and flu	840 (87.9)	252 (26.4)	< 0.0001

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