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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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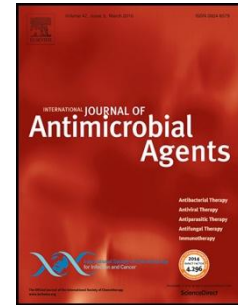
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Highlights

- 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.

50

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

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55 **1. Introduction**

56 Nowadays, the spread of antimicrobial resistance (AMR) within pathogenic microorganisms
57 represents a seriously alarming threat to global public health, leading to prolonged hospital stays,
58 treatment failures, and increased healthcare costs [1,2]. In Europe, many efforts have been put into
59 educational programs aimed at prescribers and healthcare professionals to optimize antimicrobial
60 therapy and reduce antimicrobial resistance. Many reports have consistently documented that these
61 interventions are fairly effective in reducing antibiotic overuse [3,4]. However, results from the last
62 2016 Eurobarometer survey, as well as from a cross-sectional study recently conducted in Italy,
63 have shown that many adults still have serious misunderstandings about antibiotics and that
64 children's basic knowledge of antibiotic use is poor [5,6]. Thus, in the past few years, a variety of
65 educational campaigns, such as the "European Antibiotic Awareness Day" led by the European
66 Centre for Disease Prevention and Control, and many other programs have been proposed to
67 improve global awareness of AMR in general public, including school-aged children [7,8].
68 In Europe, the e-Bug project, which was developed in 2006, partly funded by the European
69 Commission (DG SANCO), is a representative online education resource that aims to improve
70 young people's understanding of the importance of hygiene and responsible antibiotic use.
71 Currently e-Bug is led by the Public Health England's Primary Care Unit in England and involves a
72 consortium of 26 international partner countries [8]. In Italy, the Istituto Superiore di Sanità (ISS) is
73 the current e-Bug partner, being directly involved in public health protection [9,10].
74 In this context, we report the experience of a public engagement initiative promoted by the
75 University of Turin and funded by the Italian Ministry of Education University and Research

76 (MIUR), entitled the *Microbiological@mind project*, targeted at primary school children. The main
77 aim of the project was to educate children about microbiology, reinforcing awareness of positive
78 behaviors (i.e. hand washing, proper antibiotic use) that may ensure a safer lifestyle. Furthermore,
79 the project was in line with the European Community programs focused on extending science
80 education into primary schools to foster interest in science starting from childhood [11].
81 In addition, this initiative aimed at strengthening the relationship between the university and the
82 primary schools in the surrounding territory.

83

84 **2. Materials and methods**

85 *2.1. Project description and participants*

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

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

92 *2.2. Methodological approach*

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

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

99 *2.3. Planned activities*

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

102 infection. The workshop activities related to each main topic are described in detail in Table 1.

103 Overall, the educational content and the key learning outcomes were similar to those proposed by
104 the junior pack of the e-Bug website.

105 *2.4. Project evaluation and dissemination*

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

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

116 *2.5. Data analysis*

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

122

123 **3. Results and Discussion**

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

128 In Italy, although primary school curriculum covers the topic of human health and hygiene
129 according to the Italian National Guidelines, limited information about microbes and prudent
130 antibiotic use is currently provided within lower compulsory education [13]. Unlike many other
131 European countries, the majority of Italian primary schools are not equipped well enough to offer
132 scientific laboratory activities for their students, inasmuch as science teaching is generally more
133 concentrated in lower and upper secondary compulsory schools. Moreover, teachers in Italian
134 primary school are generalists and very few of them have a strong scientific background [11].
135 Therefore, in this context, the *Microbiological@mind project* was promoted to enrich the basic
136 scientific curriculum in primary schools through a close collaboration between schools and
137 university. This initiative was specifically targeted at primary school children, as a large body of
138 research has suggested that these early years lay a powerful foundation for subsequent lifelong
139 learning [14]. Moreover, the 9 –11 age group of students in fourth grade classes was considered the
140 most appropriate at which to aim the project. In fact, children at this age have already learned a
141 substantial amount about the natural world, and they possess reasoning processes that support
142 causal inference and evidence interpretation [14]. Moreover, teaching children quite difficult
143 microbiological concepts just before they leave primary school allows to sustain children's natural
144 and spontaneous interest in scientific knowledge, avoiding mistakes and misconceptions.
145 Based on qualitative results from students' and teachers' interviews, this public engagement
146 initiative was warmly welcomed in schools in Turin. As highlighted by school teachers involved in
147 this project, the practical work, through simple fun activities was particularly effective in
148 influencing student interest towards the microbiology subject addressed (Table 1). The hands-on
149 teaching strategy provided in a formal classroom context was easily accepted. Through this
150 approach, it was easy to motivate and interest young students, bringing scientific education and key
151 learning concepts on microbiology closer to this young audience. Previous studies have shown that
152 the use of interactive activities can greatly improve public knowledge on specific health issues such
153 as microbial infections, antimicrobial resistance and prudent antibiotic use [7,15-17]. Furthermore,

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

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

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

169 In this study, 956 questionnaires (pre- and post-activity tests), out of all those returned by school
170 teachers, were considered amenable for data analysis, with an overall true response rate of about
171 80%. Based on results from the questionnaires, lack of basic knowledge regarding antibiotics was
172 detected among the majority of the young students. As reported in Table 2, low percentages of
173 correct answers were found in the pre-test, with only 5.0 % and 12.1% of correct answers on
174 antibiotic action and use, respectively. Significant increases in knowledge were observed in the
175 post-test (about 6 weeks later), after implementation of the teaching activity. Knowledge of the
176 correct use of antibiotics for bacteria rather than viruses and other microorganisms rose from 5.0%
177 to 77.2% in the post-test ($p<0.0001$). Whereas, knowledge of the risk of bacterial resistance to
178 antibiotics from their incorrect use rose from 12.1% to 73.6% in the post-test ($p<0.0001$).

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

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

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

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

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

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207 **Competing interests:** None declared.

208 **Ethical approval:** Not required.

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

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

TOPIC	ACTIVITIES	KEY LEARNING OUTCOMES
INTRODUCTION TO MICROBES	<p><u>HARMFUL AND USEFUL MICROBES</u></p> <p>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).</p> <p>Children were taught about the microbial communities that normally exist throughout the human body.</p> <p>A simple <i>in vitro</i> experiment of the bread leavening process using baker's yeast (<i>Saccharomyces cerevisiae</i>) was carried out.</p>	<p>Microbes are everywhere and are invisible to the naked eye. They have different shapes and sizes. Some harmful microbes can make us ill.</p> <p>Many useful microbes exert beneficial relationships with the human body.</p> <p>Useful microbes also play a key role in food production.</p>
SPREAD OF INFECTION	<p><u>IMPORTANCE OF EVERYDAY HYGIENE</u></p> <p>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).</p> <p>A macroscopic examination of the different colonies of either bacteria or fungi grown onto agar plates was carried out.</p> <p>The bacterial load of every student's hands before and after hand washing was observed.</p> <p>Gram-stained slides of bacteria (<i>Streptococcus spp.</i>; <i>Staphylococcus spp.</i>; <i>Lactobacillus spp.</i>; <i>Escherichia coli</i>) were viewed under a high power microscope placed in every classroom.</p> <p>Slides of yeasts (<i>Saccharomyces cerevisiae</i>) and moulds (<i>Penicillium spp.</i>; <i>Aspergillus spp.</i>) were also observed under the microscope.</p>	<p>Infection can be spread through direct physical contact between people, airborne droplets from coughing and sneezing or from contact with surfaces and objects.</p> <p>Close environments and inanimate objects serve as resting grounds for microbes.</p> <p>Contaminated hands are the primary mode of transmission of many infectious diseases, particularly among those living in close proximity to one another.</p> <p>Hand washing is the most effective way of reducing the spread of infections caused by harmful microbes.</p>
THE BODY'S NATURAL DEFENCES	<p><u>BLOOD CELLS AND THE IMMUNE SYSTEM</u></p> <p>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.</p>	<p>The human body has many natural defences to fight infection.</p>
TREATMENT OF INFECTION	<p><u>ANTIBIOTIC ACTION AND USE</u></p> <p>The discovery of antibiotics was explained to students, giving more information on the benefits of antimicrobial drugs against bacterial infections.</p> <p>Observation of different antibiograms was carried out, followed by expert-led discussion in the classroom.</p>	<p>An appropriate use of antibiotics helps to prevent the development of antibiotic-resistant bacteria and the resulting failure of antibacterial therapies.</p>

PREVENTION OF INFECTION	<u>VACCINES</u> 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.
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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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