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Procedia - Social and Behavioral Sciences 116 (2014) 4654 – 4659
Procedia
Social and Behavioral Sciences

5th World Conference on Educational Sciences - WCES 2013

Learning science by doing: a quali-quantitative research

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Abstract

Educational interventions in school represent a primary way to introduce children to public health issues. In particular, as foodborne diseases are considered a worldwide significant problem, according to the World Health Organization (WHO), an educational program has been implemented to improve children knowledge about microorganisms' characteristics and food contamination, and their everyday behaviors concerning personal hygiene. Twelve public schools in Padua province were enrolled, for a total of 249 children attending the fifth grade of primary school. Health programs are usually targeted to adults and teenagers; a method that take into account children's peculiar learning and communicative skills was adopted. Aim of the study is to determine whether interventions based on practical activities that dynamically involve children with experiments and scientific observations are more efficient that purely theoretical programs. To assess the different effectiveness of the interventions, a between subjects experimental design has been set up, with random assignment of classes to theoretical (N=120) and practical (N=123) groups. The evaluation of children knowledge was assessed in two ways: 1) the analysis of a questionnaire collected before and after the intervention; 2) the analysis of a creative drawing about the microorganisms collected before and after the intervention that has been related to a semi-structured interview, to comprehend the meanings of the picture. Results show that although both the programs (theoretical and practical) were effective, the practical work stimulated a qualitatively deeper comprehension of the given information, especially in relation to the causal linkage between protective behaviors and control of contagion risk.

Keywords: Microorganisms, Foodborne Diseases, Educational Interventions, Quali-quantitative methods, Learn by Doing.

1. Introduction

Although important advances have been reached in public health, foodborne diseases caused by microbial action remain a significant issue to deal with. In fact, the World Health Organization (WHO) reports that up to 30% of individuals in developed countries, get ill as a consequence of: ingestion of contaminated food or water by microbial pathogens, contact with infected animals and person to person pathogens transmission. Moreover, in 2010, in EU, 5,262 foodborne outbreaks were reported, accounting for 43,473 human cases, 4,695 hospitalizations and 25 deaths (EFSA 2012). Foodborne diseases are often characterized by bland symptoms and prevention is almost always possible, nevertheless they represent a major challenge to public health due to their high cost and potentially severe consequences.

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doi:10.1016/j.sbspro.2014.01.1002

Many consumers underestimate the hazards related to inappropriate food storage, manage and consumption and risk warnings rarely meet the audience in an efficient way (Altekruse, Yang, Timbo, & Angulo, 1999). For this reason, international literature repeatedly stimulate the implementation of education and training on food safety to all age groups with a particular attention posed to the way in which messages are transmitted (Parry, Miles, Tridente, Palmer & South and East Wales Infectious Disease Group, 2004; Medeiros et al. 2001).

Regarding foodborne diseases, children deserve additional attention due to their at-risk position. Children's immune system is immature and they usually lack of proper information on hygiene and food handling. While effective strategies for improving food hygiene have been studied in previous researches (Losasso et al. 2012; Medeiros et al. 2012), little has been made to consider school as a possible context to apply food safety interventions. Furthermore, there is still non-indication for a specific school safety curriculum provided by Italian public school, even though it is indicated as essential for the development of a proper food handling practices (Haapala & Probart, 2004; Youatt et al. 1996). Additionally, implementing food hygiene interventions in school may represent a useful way to convey information to family members too, as student often share knowledge learnt at school in the home setting (Egan et al. 2008; Haapala & Robert, 2004; Iudici, 2013).

Previous researches on food safety education programs demonstrated how children, aged 9 to 12, successfully increased their knowledge and changed their behaviors (Cody & Hogue, 2003; Youatt et al., 1996; Cullen, Bartholomew & Parcel, 1997; Haapala & Probart, 2004). However, authors found that even though children understood the food handling procedures and the prevention practices to apply in everyday life, they did not caught the reasoning behind these measures. A cause-effect linkage was lacking in children's representation of microbial functioning, and the practices learnt were like a bare list of things to do without a real meaning. In order to assure the long-term effects of education programs, many researchers suggest that the awareness of the cause-effect relationship between the behavior and the concrete health benefits has to be central (Prochaska, 2008; Youatt et al., 1996).

To induce this kind of link between microbial life and microbial contamination ecology, the "learn by doing" method (Dewey, 1916; Vygotsky, 1976; Schank, 1995; Lesgold, 2001) could be appropriate. This method is characterized by 1) a "doing device"; 2) a strong link between the teaching moment and the "real life" application; 3) a "need" experienced by learners. Individuals are engaged in every minute of their life in learning ways to solve practical problems. For example it could be hard to imagine how to drive without ever putting the hands upon the wheel. Learning is essentially a discovering process: in order to effectively learn something we need to explore, explain and then generalize. In our case, if we would make children to actively observe what is invisible for them (as in the case of microorganisms), to label it so they can categorize this knowledge, and then to make them to experience how these microorganisms can interact with food and human organism, we may induce the causal linkage that precedes a deeply knowledge.

2. Rationale

A critical point in implementing interventions with children is the evaluation of effectiveness of the program. Children's linguistic production and comprehension is definitely different from adults, and it is never certain about how properly children can comprehend questionnaires' items. Inquiring the knowledge regarding hygienic and food-safety practices is problematic for adults too (Kellar & Abraham, 2005; Milton & Mullan, 2012; Romaioli, Faccio & Salvini; 2008; Faccio, Cipolletta, Dagani & Romaioli, in press) and could be even more difficult with children due to their lack of technical vocabulary; so, an easy, familiar and concrete language must be adopted both during the intervention and the results evaluation (Iudici & Faccio, 2013). For this reason, in order to assess changing in children's knowledge on microorganisms, it has been decided to implement a qualitative method to be applied together with the cognitive questionnaire (quantitative method). Children were asked to produce a creative illustration entitled "The microorganisms and I", both before and after intervention. Subsequently, 70 drawings were randomly chosen and their authors were interviewed to understand the meanings and the implicit attributions that lead the drawing creation. Even though drawings have been widely adopted in primary schools to facilitate children understanding of abstract concepts (Bird & Diamond, 1978; Castelnuovo et al, 2008; Schilling, McGuigan, & Quaker,1993), few researches investigated systematically its use in evaluation process (Schilling et al., 1993; Rennie & Jarvis, 1995; Gan, Scardamalia, Hong & Zhang, 2007; Faccio, 2011, 2012; Faccio, Belloni & Castelnuovo, 2012; Faccio, Centomo, & Mininni 2011; Faccio, Romaioli, Dagani & Cipolletta, 2012; Faccio et al., in press). It is important to underline that data collected with a quantitative method cannot be directly compared with the data produced in a qualitative way because these techniques operate by using two different paradigms (Guba & Lincoln, 1994). Even if the scientific debate tends to promote a dialogue and a comparison between these different methodologies, we must recall that the epistemological assumptions that underlie these two positions are radically different. An interaction between questionnaires and qualitative methods is possible only if we consider how different theories can be located along a *continuum* where multiple intermediate positions are possible (Hummersley, 1996) referring to different dimensions (for example: numeric *vs.* non numeric, structured *vs.* unstructured, natural *vs.* artificial). Following this, many authors affirm that it could be not only legitimate, but also productive, using these two approaches in a combined way (Reicher, 1994; Silverman, 1997; Mazzara, 2002; Costa et al., in press).

To explore this opportunity, the education program was implemented in 12 primary schools in the Padua province, North-East of Italy. Students enrolled, aged between 9 and 11 years old, were divided into two groups, theoretical and practical, to comprehend how a different educational module may produce a different acquisition of knowledge and behaviors. The theoretical module provided one single lesson in which the notions about microorganisms were explained. The practical module included two lessons, in which the same notions given to the theoretical group were combined with practical experiments that made possible the observation of microorganisms in the air, in the saliva and on hands, before and after washing them. Each student had a personal device to experience in first person this scientific procedure. Questionnaires, drawings and interviews were collected before and after intervention; in order to assure the same opportunity to all students, experiments were also made within the theoretical classes, but at the end of the study.

3. Methods

Children questionnaire was divided into two main sections and is available on request. In the first part information on respondents characteristics (gender and ethnicity) were collected. The second part, called "*Knowledge*", was based on the following nine questions of seven true-false items each: 1) *bacteria localization in the environment*; 2) *differences between viruses and bacteria*; 3) *relationships between bacteria and human body*; 4) *hands hygiene*; 5) *raw meat proper handling to reduce food-borne risks*; 6) *fruit and vegetables proper handling to reduce food-borne risks*; 7) *bacteria and food technology*; 8) *food handling hygiene*; 9) *insight into flu*. In order to compare the effectiveness of the two types of interventions in modifying children beliefs, Poisson Mixed Models for repeated measures and random intercepts (*log* as link function) were performed (Twisk, 2003) using the "*Knowledge*" scores as outcomes (dependent variables) and the questionnaire administration time (before *versus* post intervention) and the type of class (practical *versus* theoretical) as determinants (independent variables). The obtained esteem describes the differences due to the two interventions, according to the score of each topic, in terms of incident risk ratio (IRR) with the relative 95% confidence interval (95%CI).

Drawings were classified by two independent judges into diverse areas of interest (*subject*, *shape*, *context*, *captions*, *causal link between represented objects* and *microorganisms' actions*), which were composed of various mutually exclusive categories based on graphic content (Bombi, Pinto, & Cannoni, 2007). The level of inter-rater agreement for the pre-intervention drawing analysis reached a Cohen-Kappa coefficient of 0.95, that is almost perfect (Landis & Koch, 1977).

Collected interviews were semi-structured. The first question stimulated the interviewee to explain the drawing made, then there were four critical dimensions to explore: 1) what microorganisms are; 2) where they live; 3) what do they do; 4) what can I do to behave correctly. Questions used to elicit these dimensions were the same in all interviews, but the order of the questions could change between different interviews, and other questions could be asked to put children easily. The answers given by children were audiotaped, transcribed, and coded. All data were analysed using Chi-Square Test to comprehend possible differences between theoretical and practical group.

Written consent was obtained from parents or tutors.

4. Results

Theoretical and practical sample are slightly different between questionnaire and drawing analysis: 249 children were involved in the study; 87 and 162 children of theoretical and practical group respectively filled-in the questionnaire, while drawings and interviews involved 123 children of theoretical group and 120 of the practical one; 6 children were not at school in the day when post-intervention drawings were collected.

Intervention effectiveness in modifying children "Knowledge"

An overall improvement in children knowledge (total "*Knowledge*" outcome) was observed both for the practical and theoretical class as the IRRs were 1.16 (95%CI 1.12-1.19) and 1.10 (95%CI 1.05-1.15) respectively. The main improvement was evidenced for the *relationships between bacteria and human body* and the *bacteria and food technology* topics and their IRRs were 1.32 (95%CI 1.22-1.43) and 1.44 (95%CI 1.33-1.57) respectively. A significant progress in children consciousness on these two issues was observed in both the two classes for which IRRs were 1.32 (95%CI 1.19-1.46) and 1.50 (95%CI 1.35-1.67) for the practical class and 1.32 (95%CI 1.15-1.51) and 1.34 (95%CI 1.16-1.55) for the theoretical one.

In the case of the *bacteria and food technology* topic, IRRs were significant for both classes, in particular the number of correct answers post-intervention was 50% higher than in the pre-intervention (IRR 1.50, 95%CI 1.35-1.67).

The practical approach was effective also in the case of the *bacteria localization in the environment*, the *differences between viruses and bacteria*; the *raw meat correct handling to reduce foodborne risks* and the *food handling hygiene* topics as the IRRs, all statistically significant, were 1.32 (95%CI 1.20-1.46), 1.12 (95%CI 1.02-1.23), 1.11 (95%CI 1.01-1.23), 1.13 (95%CI 1.01-1.26), respectively. This result is strongly supported by the huge evidence that students find practical work relatively useful and enjoyable compared with other science teaching methods and learning activities (Cerini, Murray & Reiss, 2003; Abrahams & Millar, 2008).

Drawing analysis

After intervention, students in the theoretical group depicted standardized forms of viruses and bacteria (similar to those shown during the lessons) significantly more than practical group students (88.6% theoretical group, 75.0% the practical, $p=0.019$), whereas, in the practical group, more participants still used undefined shapes (24.2%, 10.6% for the theoretical one, $p=0.005$) such as colored points or other figures that could be compared to what children saw in the plates and in the slides used in the experiments. The contexts illustrated by students were more accurate. In particular, students in the practical group more often drew the microorganisms in the human body context (25.8% *versus* 9.8% of the theoretical one, $p=0.001$), whereas participants in the theoretical group had more difficulties finding a specific context for viruses and bacteria (71.3% *versus* 54.4% for the practical one, $p=0.017$). This is probably related to the fact that students participating in the experiments had the possibility to observe microorganisms populating in their hands and in their mouth as well. The impact of this information may have influenced their representing viruses and bacteria interacting with their own bodies. The opportunity to actively participate in the experiments induced more students in the practical group (30.8%) than the theoretical (17.1%) to clearly define in their drawings the causal linkage between the action of a microorganism and its consequences on people and on the environment ($p=0.012$). The kind of actions of the microorganisms represented by the students grew to 8.9% in the theoretical group and to 16.7% in the practical group for positive and useful actions and to 17.1% in the theoretical group and to 27.5% in the practical for negative and harmful actions.

Interview analysis

It is important to underline that the children were free to report what they thought in an evocative task. These answers have to be considered as part of an in-depth learning process, unlike during the completion of a questionnaire, for which students are obliged to give certain answers, choosing between alternatives that have already been prepared by researchers (Faccio et al., 2013; Iudici et al., 2013).

During the post-session interviews, both in the theoretical group and in the practical, there was a significant amelioration of the definitions of microorganisms as bacteria ($p<0.01$), yeasts ($p<0.01$), molds ($p<0.01$), Salmonella ($p<0.01$) and viruses ($p<0.01$) comparing with pre intervention ones; no significant differences between the two groups were observed.

In the post-intervention session, only students in the practical group continued to indicate air as a living environment for microorganisms ($p<0.01$), probably because the experiment clearly showed them how the air they breathe was populated by these invisible things. The same observation was made for the human body answer, which was significantly more present in the practical group than in the theoretical one ($p<0.01$), probably because the experiment showed students how many bacteria and other microbes are present in their saliva.

These results are interesting as this information was presented in the slideshow and video, displayed to students, in order to show that microorganisms live in the air and in the human body. The significantly greater presence of answers in the practical group related to correct descriptions of microorganisms' functioning demonstrates how the active manipulation of scientific objects during the experiments produced a more effective sedimentation of the concepts and a deeper cognitive elaboration of the observations experienced.

A significantly greater number of students from the practical group indicated spoiled food as a place where molds proliferate ($p<0.01$), whereas both didactic approaches were effective in teaching how raw meat is fraught with potentially harmful microorganisms, showing a significant difference between pre and post-intervention ($p<0.01$). Knowledge about contagion was significantly more present in the practical group (46.9%; $p<0.01$). Moreover, students in this group were also more accurate than the others in indicating how sneezing is a potential form of contagion between people (40.6%; $p<0.01$).

Regarding hand-washing as a way to prevent contagion, the effectiveness of the intervention was significant for both approaches ($p<0.01$) and, even though one of the experiments proposed to the practical group was explicitly dedicated to this topic, it seems that students from the theoretical module were able to recall this information as well, with the same accuracy.

The practical group was, however, more aware that simply placing one's hand in front of one's mouth when sneezing is an effective way to prevent contagion ($p<0.01$), whereas the theoretical group was not able to recall the same behavior. This difference is probably due to the fact that students in the practical group were more accurate in identifying sneezing as a form of contagion, whereas children from the theoretical module were not equally aware of its importance.

Lastly, the analysis of the interviews of the practical group also showed that these children more often said that the disposition of food in the refrigerator is an important way to prevent contamination ($p<0.01$).

5. Conclusions

The success of the intervention has been demonstrated both for the practical and theoretical approach even though the practical model resulted more tailored to primary school children cognitive needs. Moreover it is well known that children who become aware of good practices by practical examples and who can benefit from good facilities, will be more likely to perform long term protective hygiene related behaviours (Eves et al., 2010). Historically, many restrictions to the practical model of teaching food microbiology in the public school were cited by primary school teachers, including limited budgets, poor access to resources and inability to do experimental work with microorganisms. These justifications may meet the true about school organization only in the case of practical experiences that require expensive equipment to perform experiments or that involve manipulating microbial pathogens.

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