

CHILDREN'S CONCEPTIONS ABOUT MICROORGANISMS AND HEALTH

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Children's alternative conceptions on microorganisms and health are little studied in the literature. Several international studies have shown that these conceptions are incomplete, divergent from scientific knowledge and resistant to change, often even after formal education. This study aimed to identify children's conceptions about microorganisms and health before the formal education of this content (5th grade) and two years after (7th grade). A questionnaire consisting of closed questions was applied to 439 pupils. Most pupils associate microorganisms with the disease and recognize the reason they should be vaccinated. Contrary to results in other studies, pupils associate vaccines with disease prevention rather than disease cure. Some children do not directly associate behaviours related to their hygiene and the need to disinfect wounds with the elimination of undesirable microorganisms. Also the beneficial aspects of the microorganisms are little recognized by the pupils. Statistical analysis showed significant differences ($p < 0.05$) between the two groups in some answers. It is necessary to improve the approach to microorganisms right away in primary school. Textbooks and teachers should give more emphasis on the justification of personal hygiene and the beneficial aspects of microorganisms.

Keywords: microorganisms, alternative conceptions, health education.

INTRODUCTION

The issue of alternative conceptions has been studied in several areas by many researchers in the last 20 years. However, with regard to microorganisms, the subject is poorly studied, although there are several works that constitute an excellent contribution to this area, such as Nagy (1953), Maxted (1984), Vasquez (1985), Prout (1985), Freitas (1989), Bazile (1994), Leach et al. (1996), Kalish (1996, 1997, 1999), Au and Romo (1996), Au et al. (1999), Simonneaux (2000), Inagaki and Hatano (2002), Byrne and Sharp (2006), Jones and Rua (2006), Byrne et al. (2009), Byrne and Grace (2010), Byrne (2011), Mafra (2012), Mafra et al. (2015), Ruiz-Gallardo and Paños (2017). In general, all these studies demonstrate that children's conceptions about microorganisms are often incomplete and divergent from scientific knowledge.

Considering the relationship between microorganisms and health, many children associate the cause of the disease with environmental factors, such as bad weather, air pollution or the ingestion of contaminated food (Piko and Bak, 2006), however, one of the children's most common ideas is the link between microorganisms and disease. This is referred to in older studies such as Nagy (1953), Maxted (1984), Prout (1985) and Springer and Ruckel (1992), who emphasize the pathogenic view of microorganisms as a dominant idea in all ages. More recent studies, as Byrne (2011), report that children in early elementary school consider that all microorganisms are potentially pathogenic, highly infectious and dangerous, and are the only cause for the onset of the disease. Simonneaux (2002) adds that most children have the notion

that diseases have a purely exogenous origin, that is, a healthy individual becomes ill when he/she is "attacked" by microorganisms. The same author points out that this concept may later interfere with pupils' understanding of diseases, such as those of genetic origin, and may create learning obstacles when teaching these contents at higher levels of education. Byrne (2011) also points out that younger children tend to think that the presence of microorganisms is enough for disease to occur, and older pupils associate infection with behaviour such as touching, coughing or sneezing towards others, or eating contaminated food. In fact, the mechanism of infection is not well understood by children, especially the younger ones, and the vast majority have naïve ideas about the notion of disease and its transmission.

These ideas often remain even after addressing the issue in formal education (Kalish, 1999, Inagaki and Hatano, 2002). Au et al. (1999) also suggest that children between 8 and 9 years old understand the biological cause of diseases through the model of infection that is transmitted by common sense. Thus, Byrne and Sharp (2006) report that some pupils consider environmental conditions alone as a factor that cause diseases. On the other hand, older children associate it with poor hygiene conditions or dirty places, considering that under these conditions the microbes "gain strength" or are more likely to cause infections.

Finally, it appears that only a limited number of children recognize the benefits of certain microorganisms, e.g., those used in the production of vaccines and antibiotics (Byrne et al., 2009). The anthropomorphic attribution identified in drawings of microorganisms done by children (Byrne and Sharp, 2006; Byrne, 2011; Mafra, 2012) exhibit "good feelings", indicating that some understand that not all microorganisms are dangerous. However, although some children report the use of antibiotics to cure diseases, many are not aware of how they are produced and how they work. Similarly, Byrne (2011) states that children think that both vaccines and antibiotics are designed as medicines, i.e., both acting as curing diseases; being placed in the same therapeutic class makes the concept of prevention through vaccination difficult.

According to the above, in this study it was intended to identify the conceptions of two groups of children (one before the formal teaching about microorganisms; the other two years after) about the relation between microorganisms and health and verify if there are statistically significant differences between groups.

METHODOLOGY

This is an exploratory study in which two groups of pupils were studied: one group was in the 5th grade (10-11 years old) who had had no formal teaching on microorganisms; and the other group was of the 7th grade (12-13 years old) who had had formal teaching on this issue. They were enrolled in schools of Bragança town, in Portugal.

A questionnaire with closed questions was given to 439 pupils. The questions focused on: the importance of washing hands before meals and brushing teeth after meals; food hygiene; the perception of the role of vaccines; knowledge of the various types of disease transmission, the importance of wound disinfection and the role of microorganisms. The frequency analysis of answers was estimated and Pearson's square statistical analysis was used to determine statistically significant differences between the groups analysed, using a significance level of

95%. The ethical requirements were followed in accordance with Portuguese legislation for this purpose, and formal authorization was obtained for the development of this study.

RESULTS AND DISCUSSION

Results are presented on the pupils' answers to the questionnaire. In some questions they could only choose one alternative, but in others they could choose more than one, as indicated in each Table.

For the question "*the most important reason for washing hands before eating is ...*", it was found that 63.7% of pupils said they should do so to avoid getting sick and 34.6% because their hands may be dirty (Table 1). The attribution of disease to this behaviour may be associated with microorganisms and evidence that children know that they have them in the hands.

Table 1. Frequency of answers to the question "The most important reason for washing hands before eating is..."

	1 answer only			Total
	someone tells you	You may have on your hands dirt	you can get sick	
5th grade	2.7%	28.9%	68.4%	100.0%
7th grade	0.9%	39.4%	59.7%	100.0%
Total	1.7%	34.6%	63.7%	100.0%

We found statistically significant differences ($p < 0.05$), with a decrease in the answer "...to avoid getting sick" from 5th to 7th grade. According to Mafra and Lima (2009), in the 5th curricular programme and corresponding textbooks, all contents related to hygiene are presented as recommendations to comply with or rules of good conduct without explaining the reason for the behaviours. This incomplete approach can contribute to the strengthening of alternative conceptions and make difficult the learning of these contents at higher school levels.

In the question, "the most important reason for washing your teeth after eating is ...", the large majority of pupils (95.1%) considered prevention of dental caries (Table 2). There were no significant differences ($p > 0.05$) between the 5th and 7th grades.

Table 2. Frequency of answers to the question "The most important reason for you brush your teeth after eating is ..."

	1 answer only		Total
	Your mouth smells good	You can prevent dental caries	
5th grade	5.9%	94.1%	100.0%
7th grade	4.1%	95.9%	100.0%
Total	4.9%	95.1%	100.0%

The preventive behaviour of tooth decay is a topic widely discussed in schools and broadcasted through the media, therefore it is rooted in children's perception. However, although they recognize the importance of brushing their teeth after meals and the consequences of not doing it, they may be unaware of the cause of the problem (Mafra, 2012).

On the question of food hygiene, "the most important reason for washing fruit before eating is...", 62.5% of pupils said they should "do it because it may be dirty" (Table 3). The second most chosen option was "do it because it can hurt your belly" with 34.5% of the answers.

Table 3. Frequency of answers to the question "The most important reason for washing fruit before eating is ..."

	1 answer only			Total
	It may hurt your belly	It can be dirty	The fruits get brighter	
5 th grade	41.7%	53.5%	4.8%	100.0%
7 th grade	28.5%	70.1%	1.4%	100.0%
Total	34.5%	62.5%	3.0%	100.0%

There are significant differences between the 5th and 7th grade ($p = 0.001$). More importance was given to the problem of dirtiness by the 7th grade pupils, in line with the formal teaching at this level. These results show that more importance was given to the possible "dirtiness" and suggests that the pupils assume these procedures as a norm or rule to fulfil without, however, valuing the scientific justification to this behaviour.

Regarding the nature of vaccines, 72.6% of the pupils reported that "they are substances that protect us from certain microbes" (Table 4). However, there were significant differences between the 5th and 7th grade ($p = 0.001$) in that 7th grade gave more importance to protection given by vaccines. This difference can be justified by the fact that in the 7th grade the vaccines are part of the curricular programme and textbooks.

Table 4. Frequency of answers to the question "The sentence that best explains what a vaccine is ..."

	1 answer only			Total
	Substances that are injected using a syringe	Substances that kill microbes	Substances that protect us from certain microbes	
5 th grade	7.0%	28.3%	64.7%	100.0%
7 th grade	7.2%	13.6%	79.2%	100.0%
Total	7.1%	20.3%	72.6%	100.0%

Following this theme, it was asked "the reason why we should be vaccinated ...", where the majority of pupils (77.2%) presented a scientifically correct conception related to prevention, especially the pupils of the 7th grade (Table 5), with significant differences between the two grades ($p = 0.011$). Thus, in contrast to the results obtained by Byrne (2011), the preventive vaccine is well recognized by the pupils of this study, with only 20% of them seeing vaccines as a "cure for the disease", "killing microbes".

Table 5. Frequency of answers to the question "The main reason why we should be vaccinated is ..."

	1 answer only			Total
	Fulfil the vaccination schedule	Do not get sick	Getting good when you are sick	
5 th grade	9.6%	70.6%	19.8%	100.0%
7 th grade	6.8%	82.8%	10.4%	100.0%
Total	8.1%	77.2%	14.7%	100.0%

Concerning the question "When you hurt yourself, why should you wash the wound?", 83.8% of pupils considered "to kill the microbes" (Table 6), presenting a scientifically correct notion. There were no significant differences between the 5th and the 7th grade ($p > 0.05$). However, it should be noted that in both 5th and the 7th grades there were pupils who thought disinfecting a wound aims "to remove dirt." Regarding this option, and considering the 5th grade, this result is in the curricular programme and textbooks. In fact, the first aid topic in textbooks includes

the disinfection of wounds, which are presented as a mere cleaning procedure, presenting no reason explaining why this procedure must be done.

Table 6. Frequency of answers to the question "When you hurt yourself, why should you wash the wound?"

	1 answer only			Total
	To remove dirt	To kill the microbes	To leave no scar	
5 th grade	12.8%	82.3%	4.9%	100.0%
7 th grade	13.1%	85.1%	1.8%	100.0%
Total	13.0%	83.8%	3.2%	100.0%

Regarding how diseases can be transmitted, most children chose "when you sneeze to someone without putting a hand/arm to the front of the mouth" (88.7%, Table 7-A), and also "when you eat after playing on the soil" (61.5%, Table 7-C), both responses with significant differences ($p < 0.05$) between the 5th and the 7th grade. In the case of the response "when you eat spoiled food" (69.9%, Table 7-H) there were no significant differences ($p > 0.05$) between the two groups. These responses show the recognition of two forms of disease transmission: aerial (mostly recognized by the children of the 7th grade) and oral (recognized by both groups).

Table 7. Frequency of responses to the question "Diseases can be transmitted ..."

	more than one answer							
	A	B	C	D	E	F	G	H
5 th grade	42.5%	65.1%	49.8%	19.6%	44.6%	39.3%	45.2%	46.3%
7 th grade	57.5%	34.9%	50.2%	80.4%	55.4%	60.7%	54.8%	53.7%
Total	88.7%	10.5%	61.5%	4.6%	13.7%	40.0%	10.3%	69.9%

- A - When you sneeze to someone without putting your hand/arm in front of your mouth
 B - When you play in the sun without holding your hat on
 C - When you eat after playing on the soil
 D - When you drink a very cold drink
 E - When you play in the rain
 F - When you get bitten by a dog
 G - When you get too cold
 H - When you eat spoiled food

With regard to the places where one can find microbes, it was found that the answers "in the mouth" and "on the skin" only 17.9% and 31.4% of the answers, respectively, were found (Table 8-D and -E), with no differences between the 5th and 7th grade ($p > 0.05$). This is to say that in both groups there is poor knowledge of the presence of microorganisms in these human body areas. Despite being a content addressed in the 7th grade, most pupils keep a non-scientific conception, resisting to change. This result shows an incomplete or inadequate teaching-learning process regarding mouth hygiene (brushing teeth) and body care.

Table 8. Frequency of answers to the question "Microbes can be found ..."

	more than one answer								
	A	B	C	D	E	F	G	H	I
5 th grade	38.2%	47.1%	43.7%	54.8%	42.2%	61.6%	42.5%	78.9%	45.9%
7 th grade	61.8%	52.9%	56.3%	45.2%	57.8%	38.4%	57.5%	21.1%	54.1%
Total	44.8%	30.1%	44.9%	17.9%	31.4%	21.1%	42.6%	4.6%	62.5%

- A - In the air you breathe
 B - In soil
 C - In the food you eat and drink
 D - In your mouth
 E - On your skin
 F - In animals
 G - In sewage waters
 H - In the plants
 I - In the trash

The most frequent responses to the question "what can microbes do ..." the answers "causing disease" (96.6%, Table 9-H), "spoiling food" (90.4%, Table 9-E) were the most selected ones, without significant differences between groups ($p > 0.05$). Also the option "cleaning sewage water" (42.6%, Table 9-F) showed no significant differences ($p > 0.05$) between groups. However, the 5th grade pupils answered more frequently than those of the 7th grade ($p < 0.05$) in "pollute water" (72.3%, Table 9-D) and "food production" answers (44.9%, Table 9-A), although these topics are worked in the 6th grade. On the other hand, the 7th grade pupils answered more frequently than those in the 5th grade ($p < 0.05$) in the option "make medicines" (51.8%, Table 9-C).

Table 9. Frequency of answers to the question "What can microbes do?"

	more than one answer							
	A	B	C	D	E	F	G	H
5th grade	27.1%	57.1%	21.3%	53.6%	46.9%	53.8%	44.4%	86.4%
7th grade	72.9%	42.9%	78.7%	46.4%	53.1%	46.2%	55.6%	93.6%
Total	44.9%	51.7%	51.8%	72.3%	90.4%	42.6%	48.2%	96.6%

A - Food production (bread, yogurt, cheese)

B - Making glass

C - Making medicines

D - Polluting water

E - Spoiling food

F - Cleaning sewage water

G - Wood

H - Cause disease

Pupils' answers to the above questions denote a strong negative connotation towards microorganisms, which is in agreement with those results described by Byrne and Grace (2010), Byrne (2011) and Mafra (2012). This may be related to the approach to microorganisms in the textbooks of primary school, where microorganisms are only and exclusively presented as associated with disease and pollution (Mafra and Lima, 2009). Also hygiene content is addressed as recommendations to comply or rules of good conduct, without explaining the reasons for the advised behaviours (Mafra et al., 2015).

Most children recognize why they should be vaccinated and associate vaccines with disease prevention rather than with "cure for disease," which are in agreement with results found by Byrne (2011). The percentage of pupils who consider the vaccine as a "cure for the disease" may be explained by the fact that in primary school this issue is quite valued, in particular the vaccination (as a rule) and the vaccine compliance with a timetable (Mafra, 2012).

Most children identify air and oral disease transmission, which generates the following reflection: on one hand, pupils indicate the air and food they eat and drink as places where there are microorganisms, suggesting they are aware of the ways of air and oral disease transmission; on the other hand, only a few identify the mouth and skin as places where microorganisms exist. The latter matches the reflections by Mafra and Lima (2009) who discuss the sections of the primary school programme and textbooks which address body hygiene (brushing teeth, bathing, etc.) but that do not explained why children should adopt these hygienic behaviours. In fact, pupils devalue, or do not know, that they have microbes in their mouths and skin. If they knew, it would be more likely that the recommended hygiene behaviours would be more understood and accepted, and would not be taken as a merely fulfilment of a socially correct procedure.

Most pupils recognize why children should disinfect wounds, but some associate the process to the need to simply remove the dirt from the wound. This result may be related to the way

the topic is presented in the primary school curriculum programme, where there is no explanation for the reason of disinfecting wounds.

The results also show that when referring to the beneficial aspects of microorganisms, even after they have had the formal teaching on this topic, pupils retain little of certain microorganisms' benefits, in particular in favour of humans.

The results as a whole, also indicate that there are scientifically incorrect conceptions prevailing in the 7th grade pupils, even after this topic is taught in formal teaching.

This leads to the identification of conceptions resistant to change and to a reflection on how the contents should be treated in the teaching and learning process, in the perspective of an effective conceptual change. It is important to make children know and understand, from an early age, the reason why they should adopt certain behaviours associated with their personal hygiene, giving them scientific significance and thus contributing to the increase their scientific and health literacy.

CONCLUSIONS

Most pupils associate microorganisms with disease and recognize the reason they should be vaccinated by associating vaccines with disease prevention rather than disease cure.

Some children do not directly associate behaviours related to their hygiene and the need to disinfect wounds with the elimination of undesirable microorganisms. Also pupils, in general, do not recognise the beneficial aspects of microorganisms.

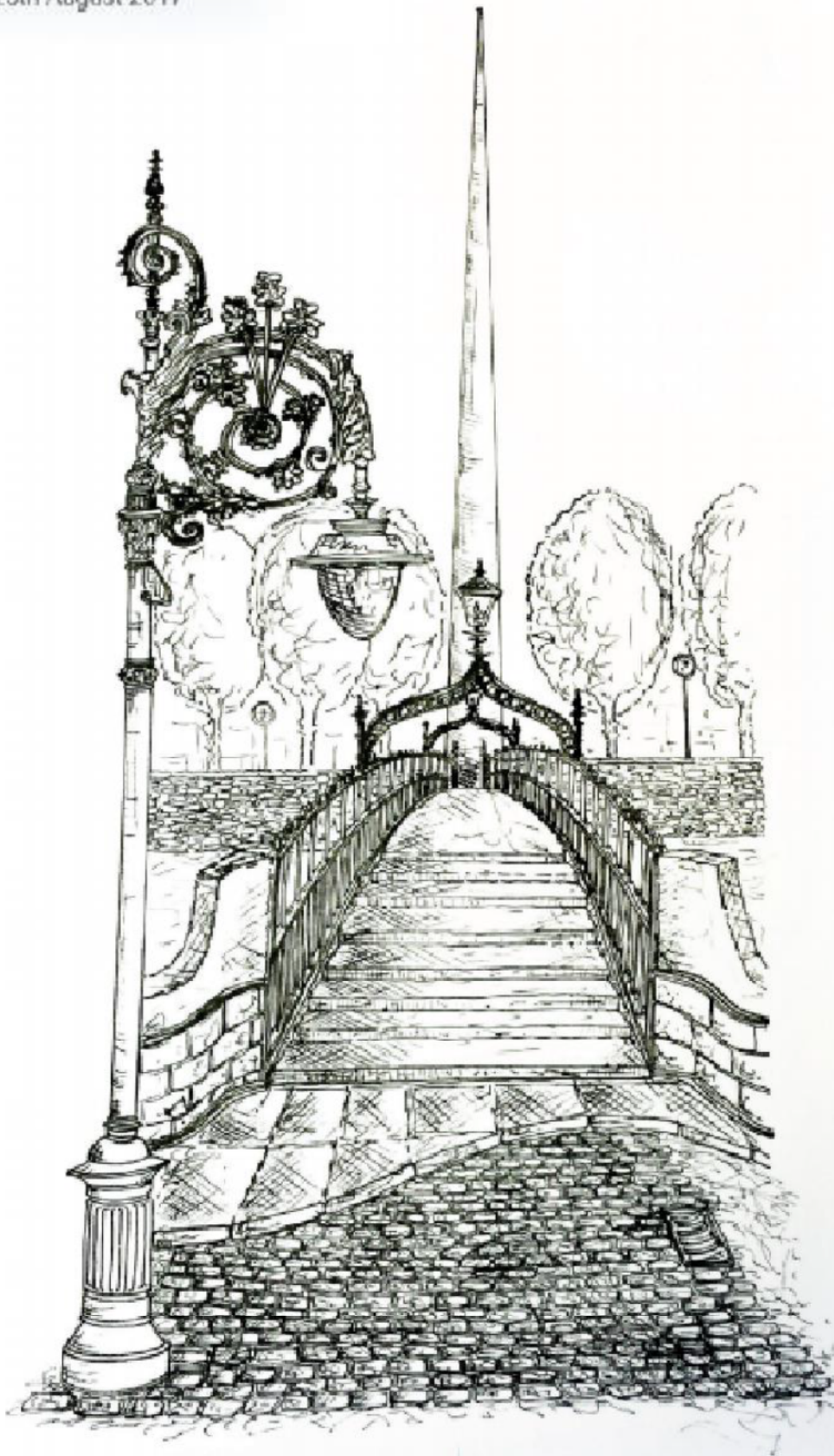
It is necessary to change the teaching and learning process of microorganisms at the level of the Primary School. Should the textbooks and teachers give more emphasis to the explanation of personal hygiene as well as to the beneficial aspects of microorganisms?

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