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Alternative Conceptions about Micro-organisms are Influenced by Experiences with Disease in Children

Pavol Prokop*, Jana Fančovičová and Adriána Krajčovičová
Faculty of Education, Department of Biology, Trnava University, Trnava, Slovakia

Children's ideas concerning natural phenomena often differ from those of scientists, and these ideas are termed as alternative conceptions. The prevalence of alternative conceptions is highest among young children who possess less experience with the natural world as compared with adults. Children's ideas about micro-organisms are of special importance, because an improved awareness of them may reduce risk of contamination by pathogenic infection. We investigate in this paper how individual differences in vulnerability to disease influence expressions of conceptions regarding micro-organisms amongst kindergarten children. More disease-vulnerable children drew smaller micro-organisms and used darker colours when drawing them compared to their healthier counterparts. The children's drawings were not influenced by gender differences. Interviews showed that all the children knew that micro-organisms are somewhere in the human body and that their placement in all probability reflects their own experiences with disease. Perhaps surprisingly, hands were one of the least frequently cited sources of micro-organisms which may reflect low awareness on the part of children regarding threats from potentially pathogenic bacteria. These results support the universality of children's conceptions regarding micro-organisms and suggest further implications both for teaching and research regarding children's conceptions.

Keywords: *Alternative conceptions; Children; Disease; Micro-organisms*

Introduction

Before beginning school, children hold conceptions about phenomena which obviously differ from those which are scientifically accepted as correct. This discrepancy has given rise to the term alternative conceptions (Carey 1985), often considered as fragmented pieces of knowledge (diSessa 1993). A number of authors agree that alternative conceptions are poorly articulated, internally inconsistent, highly dependent on context (Windschitl and Andre 1998) and are products of direct observation, the mass media and

*Corresponding author. Faculty of Education, Trnava University, Department of Biology, Priemyselná 4, 918 43 Trnava, Slovakia. Email: pavol.prokop@savba.sk

peer culture (Mintzes and Wandersee 1998; Munson 1994; Yen, Yao, and Chiu 2004). A younger age is typically associated with a greater prevalence of alternative conceptions amongst children (Carey 1985, Prokop, Kubiatko, and Fančovičová 2007; Prokop, Prokop, and Tunnicliffe 2008).

Micro-organisms are interesting objects for studying alternative conceptions, because their impact on human lives is extraordinarily high, given that diseases caused by micro-organisms are (and historically were) responsible for a large variation in human mortality and morbidity (e.g. Prokop and Fedor 2013; Schaller and Murray 2011). This reinforces the importance of research on children's conceptions of micro-organisms. Previous research demonstrated that micro-organisms are, according to children, small animals causing diseases which cannot be seen without magnification (Byrne 2011; Byrne, Grace, and Hanley 2009; Nagy 1953). The pathogenic perception of micro-organisms by children is a dominant idea held by individuals of all ages (Byrne 2011; Byrne, Grace, and Hanley 2009; Nagy 1953; Prout 1985; Springer and Ruckel 1992).

Personal experiences with micro-organisms such as being ill, for example, may influence children's expressions of their ideas about them (Byrne 2011). This idea, however, was not supported by empirical evidence. Previous research revealed that more spider-fearful individuals drew larger spiders on an index card compared with their less fearful counterparts (Vasey et al. 2012). This suggests that drawings mirror child's feeling. Because the drawing method is a frequently used method to investigate a child's expressed model of a particular phenomenon (e.g. Prokop, Prokop, and Tunnicliffe 2008; Reiss et al. 2002; Strommen 1995), it is important to examine the underlying mechanisms influencing the expressions of a child's mental models. We hypothesise that children's drawings of micro-organisms are influenced by their personal experiences with disease (Hypothesis 1). In particular, we predict that children with more experience with disease will draw micro-organisms larger than those who have less experience with disease. We further predict that children with more experience with disease will draw micro-organisms in the human body more frequently and with a more negative appearance (no smile) than those who are less experienced with disease.

Child's experiences with micro-organisms may be further expressed in the colour of their drawings. The perceived health affects the mood (Watson 1988) and the mood is associated with the colour preference (Boyatzis and Varghese 1994; Wexner 1954; Zentner 2001). Carruthers et al. (2010), for example, found that dark colours are associated with depression and depression is inversely associated with perceived health (Kung et al. 2013; Zubaran et al. 2010). In line with this reasoning, we hypothesise that children with more experiences with disease use dark colours when drawing micro-organisms compared with children who have less experiences with disease (Hypothesis 2).

Although the distribution of alternative conceptions is predicted as not being sex-specific (Mintzes and Wandersee 1998), certain gender differences were found. Prokop, Prokop, and Tunnicliffe (2008) demonstrated, for example, that females incorrectly thought that some invertebrates have bones inside their bodies. Although similar patterns were found amongst boys, misclassification of invertebrates was significantly higher in females compared with males (Prokop, Prokop, and Tunnicliffe 2008). Reiss et al. (2002) found that children's ideas about the human body are somewhat better in males in some countries. Concerning micro-organisms, females suffer from higher levels (i.e. both

prevalence and severity) of morbidity (e.g. Waldron 1983), have a worse self-rated health and more hospitalisation episodes than males (Case and Paxson 2005). This would suggest that females might exhibit greater concerns about micro-organisms than males (Hypothesis 3). More specifically, we predict that drawings of micro-organisms by females are larger, darker, with a negative appearance (no smile) and more frequently drawn inside the human body compared with drawings made by males.

Methods

Participants

A total of 181 children (93 girls) with a mean age of 5.3 years (SE = 0.06, range: 4–8 years) attending four kindergarten schools (each located in a different small town) in Western Slovakia participated in this study. We used a convenience sample where we had personal contacts with the teachers. The head of each school was contacted first with our intention to carry out research, but without explaining specific hypotheses tested by this study. Written consent was consequently received from the parents who approved the participation of the children in the research. Parents were then asked to kindly respond to a series of questions regarding the health status of their children (below). Data from all four schools were pooled, because no apparent differences between them were found.

Measuring Perceived Health

The parents received a questionnaire where we asked whether their children experienced common infectious diseases such as measles and chickenpox. We further asked about a number of additional infectious diseases which children experienced over the past 365 days (e.g. airway inflammation, gastroenteritis, infectious mononucleosis, fifth's and sixth's disease). Fifth disease is *erythema infectiosa* caused by the human parvo virus B19–3. Sixth disease (roseola) is *exanthem subitum* caused by human Herpes virus type 6. An additional, open-ended question provided an opportunity for parents to describe other health problems which their children had over the past 365 days. The scores were then summarised in order to form a composite index (hereafter the Disease Index) meaning that the high score represented a frequent incidence of infectious diseases and a low score represented a low frequency of infectious diseases. Parents also rated the frequency of infectious diseases in their children on a four-point scale (1 = more than eight-times, 4 = never) and the overall perceived health status of their children (1 = extremely good, 5 = extremely bad) over the past 365 days in order to check the reliability of data for particular infectious diseases. As expected, the Disease Index score negatively correlated with the frequency (Partial correlation controlled for the effect of age and gender, $r = -0.33$, $p < 0.001$, $N = 181$) and positively with the perceived health status of children (partial $r = 0.26$, $p < 0.001$, $N = 181$) providing certain evidence about the reliability of the parents' ratings.

An Analysis of Children's Drawings and Interviews

Children were instructed to draw 'What do you think Bacillus looks like?' We avoided the term micro-organism, because our experience suggests that it is an unfamiliar word for most

kindergarten children. Our suggestion is in agreement with the higher frequency of word Bacillus (*bacil*) compared with the word micro-organism (*mikroorganizmus*) in Slovak language. The drawing instruction was preceded by a brief discussion regarding the functioning of the human body. Each child made his or her drawing individually, when sitting at the table with a clean sheet of A4 paper and a number of coloured pencils to not constrain the children's choices of colour selection. The children were not allowed to copy the drawings from one other. No time limits were given for the completion of the drawings.

Half of children were subjected to semi-structured interviews. The interview immediately followed the completed drawings and did not exceed 5 min. The children were asked what they drew and where the Bacillus occurs (inside or outside the human body) and in which organs it would be most frequently found.

The size of the micro-organisms drawn by the children was measured with callipers (longest length and width) and these data were used to calculate the total area of each micro-organism. When there was more than one micro-organism in the drawing, only one was randomly selected for the total area calculations. We further counted the number of 'legs' and 'hands' (if any) of each micro-organism, the coded postures (see Results for more details) and the overall appearance of the micro-organisms. The colour of the drawings was coded as uni-coloured or multi-coloured and dark or light. In case of multi-coloured drawings, the colour that prevailed was used for definite categorisation regarding the dark/light category.

Statistical Analyses

Data on both the Disease Index and the total area of the micro-organisms were not normally distributed (Kolmogorov–Smirnov tests, both $p < 0.05$). Thus, these data were Box-Cox transformed and the normality was achieved (Kolmogorov–Smirnov tests, both $p > 0.2$). This procedure allowed us to use parametric statistics.

Results

Descriptive Analyses

A total of 129 children (71%) drew one micro-organism and others drew two or more micro-organisms in their drawings. Typical postures were standing (63 children, 34%), jumping (32 children, 18%), swimming (24 children, 13%), attacking the human body (15 children, 8%), reproducing (14 children, 8%) and few others. About half of the children (86 children, 48%) drew the whole bodies of micro-organisms, while others drew only certain body parts such as 'heads', 'legs' or 'hands'. The length of the micro-organisms ranged between 4 and 30 cm. The typical shape of the micro-organisms was circle-like (91 children, 50%), a human figure (50 children, 28%) and others (particularly rectangles or triangles). Most of the micro-organisms had two 'hands' (94 children, 52%), no 'hands' (73 children, 40%) or ≥ 4 'hands'. Similarly, two 'legs' (89 children, 49%), no 'legs' (46 children, 25%) and ≥ 3 'legs' were most frequently drawn by the children (Figure 1). About half of the children drew multi-coloured micro-organisms (99 children, 55%) and the remaining children created uni-coloured drawings (Figure 2).

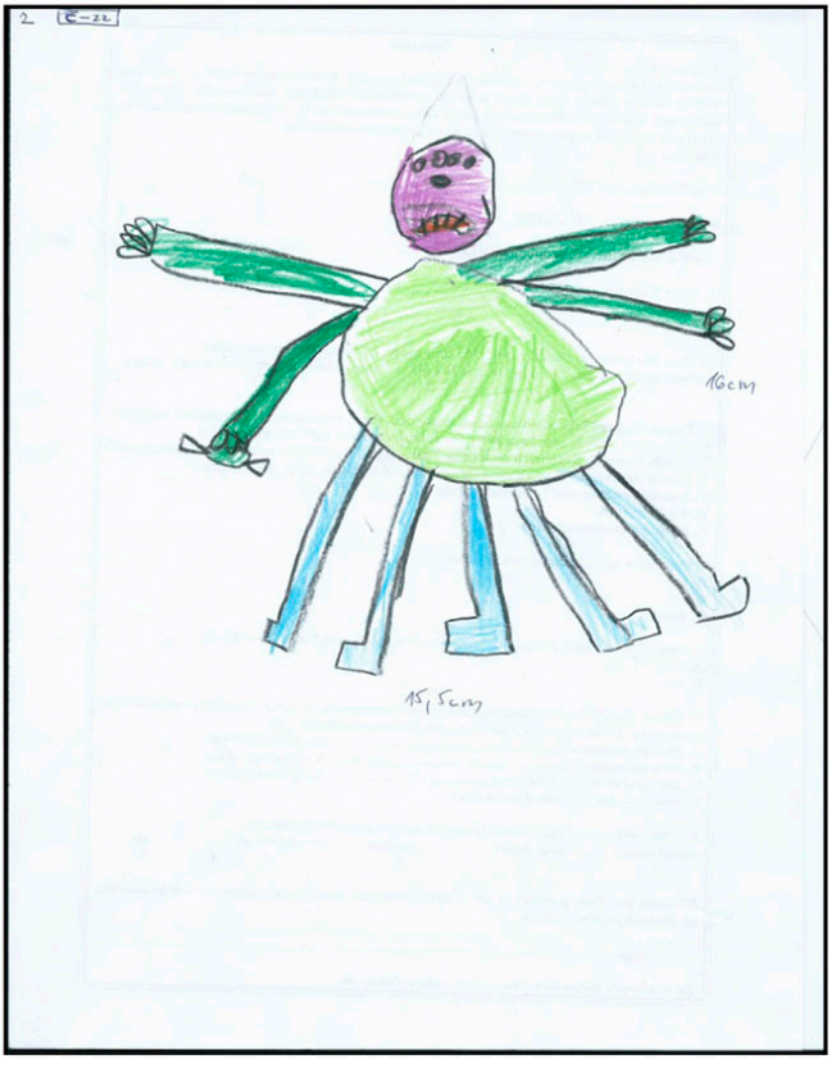

Figure 1. Representation of a micro-organism with multiple 'legs' and 'hands' by children

The Size of the Drawings

Multiple linear regression with the Disease Index, age and gender as independent variables on the total area of micro-organisms drawn by children resulted in a statistically significant model ($R^2 = 0.08$, $F(3,177)$, $p = 0.002$). As expected, the Disease Index uniquely predicted the area of micro-organisms drawn by children, although in an opposite direction from what we expected ($\beta = -0.28$, $p = 0.0001$, Figure 3). Neither age nor gender was correlated with the area of micro-organisms ($\beta = 0.07$ and 0.01, both $p > 0.3$, respectively). Of interest is the fact that if we controlled the micro-organism's area for the number of microbes being drawn, the result remained almost identical. These results suggest that children who experienced more infectious diseases, drew micro-organisms of a smaller size than those who were less frequently ill.

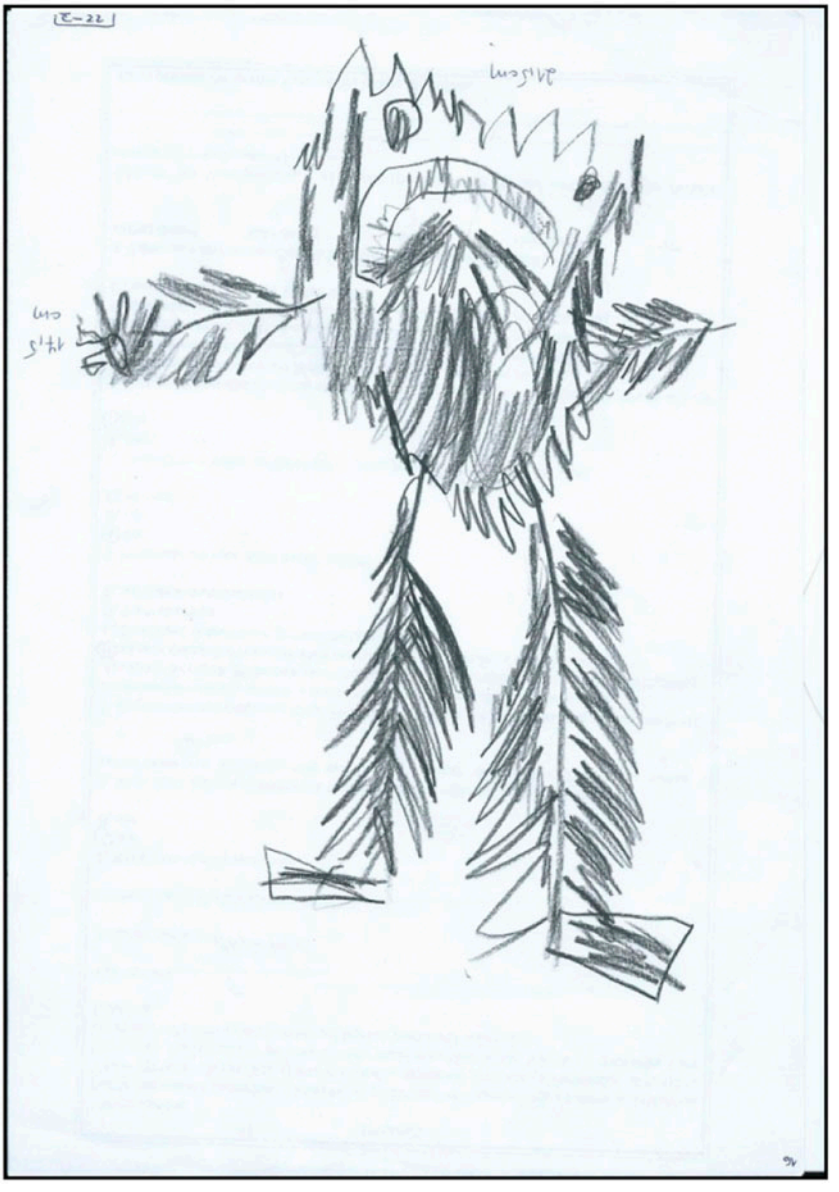

Figure 2. Uni-coloured (dark) drawing of a micro-organism

The Colour of the Drawings

A total of 67 children (37%) drew micro-organisms with dark colours (particularly with black, dark blue or dark brown). The logistic regression with the Disease Index, age and gender as independent variables on the colour of micro-organisms being drawn (dark vs. light) revealed that the Disease Index predicts the colour of micro-organisms (Wald's $\chi^2 = 3.95$, df = 1, $p = 0.047$). Specifically, children with a higher incidence of infectious

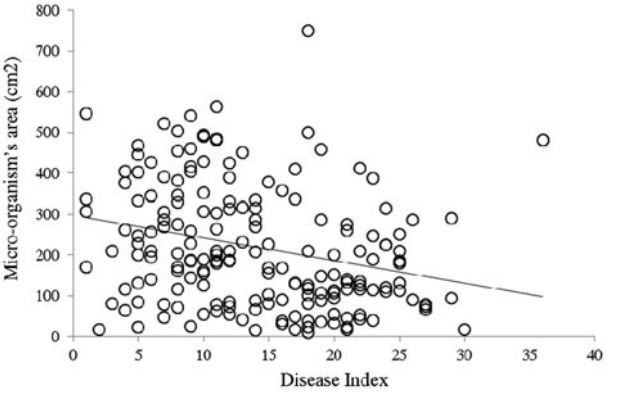

Figure 3. The negative relationship between Disease Index and micro-organisms area measured from children's drawings. The regression curve is created from raw, non-transformed data

diseases used dark colours when drawing micro-organisms more frequently than their less disease-vulnerable counterparts. Neither age nor gender was associated with the use of dark colours in drawings (Wald's $\chi^2 = 0.51$ and 0.43, df = 1, both $p > 0.47$, respectively).

Number of Micro-organisms, Appearance and the Number of 'Limbs'

A series of logistic regressions with the same predictors as in the previous analysis revealed that girls drew micro-organisms with a smile more frequently than boys (70% vs. 53%, Wald's $\chi^2 = 6.02$, df = 1, $p = 0.014$). Other variables were not significant (all $p > 0.09$). A majority of the children (133/181, 73%) drew one micro-organism while others drew two or more; drawing one or more micro-organisms on the paper was not influenced by any variable (all $p > 0.14$). Regarding 'limbs' on micro-organisms, Analysis of Covariance with the number of 'limbs' as a dependent variable demonstrated that older children drew more 'limbs' on the micro-organisms compared with younger children ($F(1,177) = 4.02$, $p = 0.046$, $\beta = 0.15$). Neither the Disease Index nor gender influenced the number of 'limbs' (al $p > 0.37$).

Placement of Micro-organisms

Interviews. Responses regarding placement of micro-organisms were obtained from interviews with 96 children (53% of the total sample). All these children reported that micro-organisms are somewhere in the human body. The most frequently cited organs or body parts were intestines (or 'somewhere in the abdomen') (16/96 children, 17%), followed by throat (14/96 children, 15%), oral cavity (10/96 children, 10%) and ears (9/96 children, 9%). Additional body parts, such as hands, lungs, eyes and certain others were always reported by less than 8% of the children, respectively. Since there were no children responding that micro-organisms are outside human bodies, no further comparison was possible.

Drawings. A total of 88 (49%) children placed micro-organisms somewhere inside the human body or drew an attack of a micro-organism on the body. Placing micro-organisms in the human body was not affected by the Disease Index or gender (Wald's $\chi^2 = 0.87$ and 1.02, df = 1, both $p > 0.31$, respectively). As the child's age increased, the likelihood of placing a micro-organism into the body increased (Wald's $\chi^2 = 20.77$, $p < 0.001$).

Discussion

The primary idea of this paper was to examine whether personal experiences with disease influence children's conceptions of micro-organisms. These results extend previous reports on conceptions about micro-organisms by children (Byrne 2011; Byrne, Grace, and Hanley 2009). Typical, humanised representations, or cartoon-like drawings of micro-organisms which are able to move, or have limbs drawn by the majority of children are in full agreement with the reports of Byrne, Grace, and Hanley (2009) and Byrne (2011) which are based on somewhat older children. These results support the idea that alternative conceptions are universal across cultures and age groups (Mintzes and Wandersee 1998).

Placements of micro-organisms in the human body by children in all probability reflect their own experiences with disease. Most children stated that micro-organisms are 'somewhere in the abdomen' and two cross-sectional surveys have shown that acute abdominal pain accounts for 4–5% of paediatric outpatient encounters (Patel 2000). Micro-organisms reported in the throat may reflect a sore throat which is obviously associated with pharyngitis which accounts for 6% of visits by children to family medicine physicians and paediatricians (Nash et al. 2002). The oral cavity would reflect micro-organisms causing tooth decay; a survey published by the Centers for Disease Control and Prevention (2012) indicated that 42% of children aged 2–11 have dental caries in their primary teeth, with an average of 1.6 decayed teeth per child. Acute otitis media, which may reflect reports of micro-organisms in ears, is the most frequent paediatric bacterial infection, affecting up to 75% of children at some time before age 5 years (Klein 1994).

Apart from descriptive analyses, this paper tested three hypotheses, with some of them being supported. The first hypothesis dealt with the association between the size of the micro-organisms drawn by children and their history of infectious diseases. We hypothesised that children's drawings of micro-organisms are influenced by their personal experiences with disease (Hypothesis 1). In principle, the hypothesis received some support, because the association between the area of the micro-organisms and the number of overcome diseases reported by the parents was statistically significant. The direction of the correlation indicated, however, the opposite result, meaning that children who were more vulnerable to infectious diseases had drawings with smaller micro-organisms than their healthier counterparts. We originally thought that children with poorer health would exaggerate the size of the micro-organisms, similarly as most spider-fearful individuals drew spiders about 50% longer than the least fearful individuals (Vasey et al. 2012). Disease, however, triggers the immune system (Janeway et al. 2001), while the emotion of fear activates certain brain centres, particularly amygdala (Davis 1992; Ledoux 2003). This is

in all probability the reason why outcomes of disease experiences are different from those motivated by fear. One explanation for a tendency to draw smaller micro-organisms by less-healthy children may be that these children are more familiar with diseases and, thus, they do not view disease as a dangerous threat. Further research on clinical samples of children with chronic diseases would provide more information about whether perception of micro-organisms is affected by more and less serious diseases. Alternatively, less-healthy children could receive more information from their parents or physicians regarding the nature of their diseases, and, thus, their ideas about the size of the micro-organisms are more accurate than conceptions held by healthy children.

A further two predictions failed to provide any support for Hypothesis 1. Micro-organisms were placed in human bodies regardless of experiences with diseases and the appearance of the micro-organisms (the presence of a smile or not) seems to also have not been influenced by the individual's history of infectious disease. Why the absence of smiles was not associated with disease remains unclear. Interviews with children showed, however, that all the children were aware that micro-organisms occur in human bodies (see also Byrne, Grace, and Hanley 2009) and the low variability in the children's knowledge may be responsible for the null results.

Our second hypothesis dealt with the colour of the children's drawings. In particular, we hypothesised that darker drawings of micro-organisms may be associated with vulnerability to diseases due to a negative mood (Watson 1988). This hypothesis received statistical support and suggests that children who have more experience with diseases perceive micro-organisms more negatively than their healthier counterparts. Although preferences for dark colours are associated with a negative mood (e.g. Boyatzis and Varghese 1994; Carruthers et al. 2010; Zentner 2001), we did not measure the actual mood of children; thus, the proposed link between the colours of the drawings and health remains hypothetical and more direct investigation is needed. The colour of the children's drawings may, however, reveal more information about children's experiences with disease, as expected.

Our third hypothesis was based on increased concerns about diseases amongst females (Case and Paxson 2005; Waldron 1983). A number of authors have argued that females care for children; thus, their concerns regarding disease threat have an evolutionary rationale (e.g. Curtis, Aunger, and Rabie 2004). We did not detect any differences in alternative conceptions or their expressions (e.g. colours, the presence of a smile or the size of the micro-organisms) in relation to gender. This provides support for the idea that alternative conceptions are distributed in males and females similarly (e.g. Prokop, Kubiatko, and Fančovičová 2007; Trowbridge and Mintzes 1988; Tunnicliffe and Reiss 1999). Concerning the possible effects of the individual's history of disease, certain studies have indicated that the perceived vulnerability to diseases is similar between males and females (e.g. Duncan and Schaller 2009; Prokop and Fančovičová 2011; Prokop, Fančovičová, and Fedor 2010). Alternatively, sex-specific differences in the perception of micro-organisms may appear later in life; thus, research with older children may provide different results.

Educational Implications

Typically, initial ideas about micro-organisms are as circle or human-like shapes. The circle-like shape is most compatible with the actual shape of numerous bacteria or viruses

(e.g. influenza, HIV). Teachers should use pictures of diverse micro-organisms to improve children's ideas about their appearance.

Individual experiences with diseases influence the expressions of children ideas regarding micro-organisms. One possibility is that children with a rich history of diseases know more about them than those who are healthier; these children may implement their experiences/knowledge in school projects and communicate their knowledge to other children. Personal experiences with disease may be further explored through discussions where children may be stimulated to hypothesise about the origin of common diseases and about 'what micro-organisms in our bodies want.'

Children should be taught about the causes of diseases; people can die or be impaired because of (i) chronic somatic diseases (e.g. cancer, diabetes mellitus), (ii) infectious and parasitic diseases (e.g. tuberculosis, plague) and/or (iii) adverse environmental conditions (e.g. famine, dryness) (Thomas et al. 2004). Problem-based learning and critical thinking can be used to examine human health problems from the perspective of these three categories.

Several research projects have shown that people (Aiello et al. 2003; Hedin et al. 2012), particularly children (Martínez-Bastidas et al. 2014), have pathogenic micro-organisms on their hands. By touching toys or through direct contact with their peers, children are at risk of being infected by disease. Children rarely reported, however, the presence of micro-organisms on hands (less than 8% of children). Awareness of the potential risk from bacteria on one's hands along with hygiene-promoting campaigns (Dodrill et al. 2011) should be employed in order to minimise the risk of being contaminated. Note that less than 17% of the world population washes their hands after using the toilet (Wolf et al. 2014) suggesting that this area needs urgent attention.

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References

Aiello, A. E., J. Cimiotti, P. Della-Latta, and E. L. Larson. 2003. "A Comparison of the Bacteria Found on the Hands of 'Homemakers' and Neonatal Intensive Care Unit Nurses." *Journal of Hospital Infection* 54 (4): 310–315.

Boyatzis, C. J., and R. Varghese. 1994. "Children's Emotional Associations with Colors." *The Journal of Genetic Psychology* 155 (1): 77–85.

Byrne, J. 2011. "Models of Micro-organisms: Children's Knowledge and Understanding of Micro-organisms from 7 to 14 Years Old." *International Journal of Science Education* 33 (14): 1927–1961.

Byrne, J., M. Grace, and P. Hanley. 2009. "Children's Anthropomorphic and Anthropocentric Ideas About Micro-organisms." *Journal of Biological Education* 44 (1): 37–43.

Carey, S. 1985. *Conceptual Change in Childhood*. Cambridge, MA: MIT Press.

Carruthers, H. R., J. Morris, N. Tarrier, and P. J. Whorwell. 2010. "The Manchester Color Wheel: Development of a Novel Way of Identifying Color Choice and its Validation in Healthy, Anxious and Depressed Individuals." *BMC Medical Research Methodology* 10. Article ID: 12.

Case, A., and C. Paxson. 2005. "Sex Differences in Morbidity and Mortality." *Demography* 42 (2): 189–214.

Curtis, V., R. Aunger, and T. Rabie. 2004. "Evidence that Disgust Evolved to Protect from Risk of Disease." *Biology Letters* 272 (S4): 131–133.

Davis, M. 1992. "The Role of the Amygdala in Fear and Anxiety." *Annual Review of Neuroscience* 15: 353–375.

diSessa, A. A. 1993. "Toward an Epistemology of Physics." *Cognition and Instruction* 10 (2–3): 105–225.

Dodrill, L., W. P. Schmidt, E. Cobb, P. Donachie, V. Curtis, and M. de Barra. 2011. "Male Commuters in North and South England: Risk Factors for the Presence of Faecal Bacteria on Hands." *BMC Public Health* 11. Article ID: 31.

Duncan, L. A., and M. Schaller. 2009. "Prejudicial Attitudes Toward Older Adults May be Exaggerated When People Feel Vulnerable to Infectious Disease: Evidence and Implications." *Analyses of Social Issues and Public Policy* 9 (1): 97–115.

Hedin, G., A. Blomkvist, M. Janson, and A. Lindblom. 2012. "Occurrence of Potentially Pathogenic Bacteria on the Hands of Hospital Patients Before and After the Introduction of Patient Hand Disinfection." *Acta Pathologica, Microbiologica et Immunologica Scandinavica* 120 (10): 802–807.

Janeway Jr, C. A., P. Travers, M. Walport, and M. Shlomchik. 2001. *Immunobiology: The Immune System in Health and Disease*. 5th ed. New York: Garland Science.

Klein, J. O. 1994. "Otitis Media." *Clinical Infectious Diseases* 19: 823–833.

Kung, S., R. D. Alarcon, M. D. Williams, K. A. Poppe, M. Jo Moore, and M. A. Frye. 2013. "Comparing the Beck Depression Inventory-II (BDI-II) and Patient Health Questionnaire (PHQ-9) Depression Measures in an Integrated Mood Disorders Practice." *Journal of Affective Disorders* 145 (3): 341–343.

LeDoux, J. 2003. "The Emotional Brain, Fear, and the Amygdala." *Cellular and Molecular Neurobiology* 23 (4/5): 727–738.

Martínez-Bastidas, T., N. Castro-del Campo, K. D. Mena, N. Castro-del Campo, J. León-Félix, C. P. Gerba, and C. Chaidez. 2014. "Detection of Pathogenic Micro-organisms on Children's Hands and Toys During Play." *Journal of Applied Microbiology* 116 (6): 1668–1675.

Mintzes, J. J, and J. H. Wandersee. 1998. "Research in Science Teaching and Learning: A Human Constructivistic View." In *Teaching Science for Understanding*, edited by J. J. Mintzes, J. H. Wandersee, and J. D. Novak, 60–94. Orlando, FL: Academic Press.

Munson, B. H. 1994. "Ecological Misconceptions." *The Journal of Environmental Education* 25 (4): 30–34.

Nagy, M. H. 1953. "The Representation of Germs by Children." *Journal of Genetic Psychology* 83 (2): 227–240.

Nash, D. R., J. Harman, E. R. Wald, and K. J. Kelleher. 2002. "Antibiotic Prescribing by Primary Care Physicians for Children With Upper Respiratory Tract Infections." *Archives of Pediatrics and Adolescent Medicine* 156 (11): 1114–1119.

National Health and Nutrition Examination Survey Data 1999–2004. *Centers for Disease Control and Prevention website*. Accessed November 15, 2012. http://www.cdc.gov/nchs/nhanes.htm

Patel, H. 2000. "Abdominal Pain in Children." In *Evidence-based Pediatrics*, edited by W. Feldman, 213–228. Hamilton, ON: B.C. Decker.

Prokop, P., and J. Fančovičová. 2011. "The Effect of Owning Animals on Perceived Vulnerability to, and Avoidance of, Parasitic Diseases in Humans." *Journal of Individual Differences* 32 (3): 129–136.

Prokop, P., J. Fančovičová, and P. Fedor. 2010. "Health is Associated with Antiparasite Behavior and Fear of Disease-relevant Animals in Humans." *Ecological Psychology* 22 (3): 222–237.

Prokop, P, and P. Fedor. 2013. "The Effects of Parasites on Human Behaviour: An Evolutionary Perspective." *Problems of Psychology in the 21st Century* 5 (5): 46–64.

Prokop, P., M. Kubiatko, and J. Fančovičová. 2007. "Why do Cocks Crow? Children's Concepts About Birds." *Research in Science Education* 37 (4): 393–405.

Prokop, P., M. Prokop, and S. D. Tunnicliffe. 2008. "Effects of Keeping Animals as Pets on Children's Concepts of Vertebrates and Invertebrates." *International Journal of Science Education* 30 (4): 431–449

Prout, A. 1985. "Science, Health and Everyday Knowledge." *European Journal of Science Education* 7 (4): 399–406.

Reiss, M. J., S. D. Tunnicliffe, A. M. Andersen, A. Bartoszeck, G. S. Carvalho, S. Y. Chen, R. Jarman et al. 2002. "An International Study of Young Peoples' Drawings of What is Inside Themselves." *Journal of Biological Education* 36 (2): 58–64.

Schaller, M., and D. R. Murray. 2011. "Infectious Disease and the Creation of Culture." In *Advances in Culture and Psychology*. Vol. 1, edited by M. Gelfand, C.-Y. Chiu, and Y.-Y. Hong, 99–151. New York: Oxford University Press.

Springer, K., and J. Ruckel. 1992. "Early Beliefs About the Cause of Illness: Evidence Against Immanent Justice." *Cognitive Development* 7 (4): 429–443.

Strommen, E. 1995. "Lions and Tigers and Bears, oh my! Children's Conceptions of Forests and their Inhabitants." *Journal of Research in Science Teaching* 32 (7): 683–698.

Thomas, F., A. T. Teriokhin, E. V. Budilova, S. P. Brown, F. Renaud, and J. F. Guegan. 2004. "Human Birthweight Evolution Across Contrasting Environments." *Journal of Evolutionary Biology* 17 (3): 542–553.

Trowbridge, J. E., and J. J. Mintzes. 1988. "Alternative Conceptions in Animal Classification: A Cross-age Study." *Journal of Research in Science Teaching* 25 (7): 547–571.

Tunnicliffe, S. D., and M. J. Reiss. 1999. "Students' Understandings about Animal Skeletons." *International Journal of Science Education* 21 (11): 1187–1200.

Vasey, M. W., M. R. Vilensky, J. H. Heath, C. N. Harbaugh, A. G. Buffington, and R. H. Fazio. 2012. "It was as Big as My Head, I Swear!." *Journal of Anxiety Disorders* 26 (1): 20–24.

Waldron, I. 1983. "Sex Differences in Illness Incidence, Prognosis and Mortality: Issues and Evidence." *Social Science and Medicine* 17 (16): 1107–1123.

Watson, D. 1988. "Intraindividual and Interindividual Analyses of Positive and Negative Affect: Their Relation to Health Complaints, Perceived Stress, and Daily Activities." *Journal of Personality and Social Psychology* 54 (6): 1020–1030.

Wexner, L. B. 1954. "The Degree to Which Colors (Hues) are Associated with Mood-tones." *Journal of Applied Psychology* 38 (6): 432–435.

Windschitl, M., and T. Andre. 1998. "Using Computer Simulations to Enhance Conceptual Change: The Roles of Constructivist Instruction and Student Epistemological Beliefs." *Journal of Research in Science Teaching* 35 (2): 145–160.

Wolf, J., A. Prüss-Ustün, O. Cumming, J. Bartram, S. Bonjour, S. Cairncross, T. Clasen, et al. 2014. "Assessing the Impact of Drinking Water and Sanitation on Diarrhoeal Disease in Low-and Middle-Income Settings: Systematic Review and Meta-regression." *Tropical Medicine & International Health* 19 (8): 928–942.

Yen, C. F., T. W. Yao, and Y. C. Chiu. 2004. "Alternative Conceptions in Animal Classification Focusing on Amphibians and Reptiles: A Cross-age Study." *International Journal of Science and Mathematics Education* 2 (2): 159–174.

Zentner, M. R. 2001. "Preferences for Colors and Color-emotion Combinations in Early Childhood." *Developmental Science* 4 (4): 389–398.

Zubaran, C., K. Foresti, M. V. Schumacher, A. L. Amoretti, M. R. Thorell, and L. C. Müller. 2010. "The Correlation Between Postpartum Depression and Health Status." *Maternal and Child Health Journal* 14: 751–757.