The evolution of children's ideas on pollution in the framework of experiential and socioconstructivist activities [1]

Diane Pruneau*, Jean-François Richard, Joanne Langis, Guylaine Albert and Marianne Cormier

Département d'enseignement au primaire et de psychologie éducationnelle, Université de Moncton, Moncton, Canada
E-mail: prunead@umoncton.ca
*Corresponding author

Abstract: In a polluted village, researchers identified the initial conceptions of students on pollution and on the relationship between pollution and health. They then provided the students with a conceptual change process based on experiential and socioconstructivist activities: fieldtrips, analysis of environmental stressors, experimentation of a health improvement plan, and environmental action. Following the project, the students have broadened their conceptions on pollution even if for them pollution remains garbage detectible by their senses. They can also name many effects of pollution on their health. Research results show the usefulness and limits of the proposed conceptual change process in modifying students' ideas about pollution.

Keywords: environmental education; socioconstructivism; experiential learning; conceptual change; health and environment.

Reference to this paper should be made as follows: Pruneau, D., Richard, J-F., Langis, J., Albert, G. and Cormier, M. (2005) 'The evolution of children's ideas on pollution in the framework of experiential and socioconstructivist activities', *Int. J. Environment and Sustainable Development*, Vol. 4, No. 1, pp.17–34.

Biographical notes: Diane Pruneau is Professor of Science and Environmental Education at the Université de Moncton, Canada. She has been involved with several research projects, notably on the identification and improvement of people's relationships with their environment and on sustainability education in urban areas.

Jean-François Richard is an Associate Professor and Department Chair at the Department of Elementary Education and Educational Psychology, Université de Moncton. Dr. Richard presently teaches and does research in the fields of curriculum planning and classroom assessment. Other research interests are centred on various health issues.

Joanne Langis is currently working as a Researcher at the Université de Moncton. She coordinates many research projects conducted by the Littoral et vie Group, notably on climate change education and on behaviour change in the environment domain.

Guylaine Albert is an elementary teacher. The project presented in this paper was part of her Master's degree thesis.

Marianne Cormier is a doctoral candidate in education at the Université de Moncton. Her research focuses on science education for minority language students.

1 Introduction

Over the course of the last century, the principal types of infantile diseases have evolved a great deal. For children in industrialised countries, environmentally related diseases like asthma, lead poisoning, cancer and certain neurological or behavioural problems have progressively replaced infectious diseases [2]. Even if, in the environmental health field, it is still difficult to attribute the cause of these new diseases to pollutants or specific environmental conditions, we recognise that toxic materials are more harmful to children than adults [3]. Children's greater vulnerability can be explained by their low body weight, their developing organism, and their active and exploratory personality, among other things. Indeed, children live closer to the ground, where many toxic materials can be found (for example: carbon dioxide from car exhaust), and often put their hands in their mouths, increasing the risk of exposure [4]. Similarly, children ingest greater quantities of toxins because they breathe twice as much air, consume three to four times as much food, and drink two to seven times as much water, relative to their body weight, than adults [2]. Children are thus particularly vulnerable to pollutants present in the air they breathe, water they drink, food they eat and environments in which they grow, learn and play [3].

To protect children living in polluted regions, environmental education represents a relevant means of prevention because this type of education encourages learners' awareness of their environment's ambient conditions, as well as their active participation in solving local problems. However, ways to utilise EE in the environmental health field have yet to be developed. How do we help children living in polluted areas become aware of local hazards that can affect their health, and do so without scaring them? How do we sow the seeds of awareness that will *eventually* lead them to take action in collaboration with their families or municipality?

The purpose of this exploratory study was to describe nine and ten year old children's ideas on pollution and the pollution-health relationship, before and after an experiential and socioconstructivist pedagogical intervention. More precisely, it is a description of a *cognitive* process of conceptual change, placing the study in an analysis of awareness and local environmental knowledge, which could eventually lead to environmental action, but not in an analysis of values and abilities that would be as essential to making this environmental action a reality. In a polluted coastal village, in September 2001, fourth-grade students were interviewed in order to know their ideas (conceptions) [5,6] on pollution and the relationship between local pollution and the state of their health. The students were then invited to participate in a ten-month educational process, which included various activities allowing them to construct *broader* (more developed) ideas on pollution and the pollution-health relationship. In June 2002, researchers again interviewed the students in order to gauge the evolution of their ideas on pollution and the pollution-health relationship. This paper first presents a theoretical framework compiling the principal research on children's conceptions as well as certain pedagogical strategies susceptible of favouring conceptual change. The research approach then follows, describing the environmental situation of the village of Cap-Pelé, the participating students, the methods used for gathering and analysing the children's ideas, as well as the experiential and socioconstructivist educational process experimented with the group/class. The children's ideas on pollution and the pollution-health relationship are then summarised in comparative tables (September 2001 and June 2002). The tables are then analysed to better understand the process of conceptual change and awareness experienced by the students. The conclusion proposes a reflection on the possibilities of making nine and ten year old children's conceptions of pollution evolve.

2 Young children's ideas about pollution

Research on nine and ten year old children's conceptions of pollution is rare. Toussaint, et al. [7] and Brody [8] have found that nine and ten year olds have limited ideas on the subject. For the majority of children questioned, pollution is associated with garbage found on the ground, and so to visible pollution that can be spotted with one's senses. Similarly, children do not seem to really be aware of specific effects of pollution on their health. Brody [8], after interviewing nine and ten year olds, summarises their comments this way:

> "Pollution is what people don't want and throw on the ground … It harms animals and humans. We can see, touch, taste and smell pollution … People don't want to live with pollution." [8, p.29]

Nine and ten year old students thus conceive pollution as the presence of harmful *garbage*. They nonetheless seem incapable of identifying the precise consequences of pollution on the state of their health. Brody [8] has however encountered more developed conceptions of pollution in older students. Thirteen and 14 year olds interviewed were able to imagine pollution that was invisible to the senses:

> "Pollution comes from garbage we throw out that isn't biodegradable. It kills fish and harms the environment, plants and other living organisms. It is mostly chemical in nature … Even if we don't always see it, pollution affects our planet." [8, p.29]

The students questioned by Brody [8] did not discuss the specific consequences of various types of pollution on human health however.

3 The evolution of children's conceptions

Children's conceptions are personal interpretations of natural phenomena they believe in and use to solve problems, draw conclusions and make generalisation about the facts of daily life. Children's conceptions can be considered naïve and different from those of the scientific community, but they nonetheless stem from modes of reasoning that are organised and relevant to them. More and more, researchers consider a child's reasoning plausible and firmly based on his or her prior knowledge [9].

One of the goals of science education or environmental education (EE) at the elementary level is the evolution of children's naïve or initial conceptions into conceptions that are more thought-out and/or closer to those of the scientific community. This evolution is called *conceptual change* [10]. During this "gradual process, the initial conceptual structures based on infantile interpretations of daily experiences are continuously enriched and restructured" [11, p.28]. The cyclical process is characterised by multiple phases of inductive and deductive work [12]. This is how conceptual change supposes an important modification of students' initial ideas about a phenomenon, toward notions closer to those of accepted science. This modification of initial ideas may be:

- complete: the old concept is totally replaced by a new one [13]
- peripheral: the initial idea persists and is included in the new concept [10].

More specifically, students' initial conceptions may suffer several transformations in response to a conceptual change: concepts [14,15] may be added or subtracted [16], links between concepts can also be added or excised, or the initial ideas' structure may be radically modified [17].

In science or in environmental education, noting a conceptual change in students constitutes tangible proof that learning has occurred. The goal of conceptual change is not easy to attain however. Students begin a lesson or scientific theme with firm beliefs about a scientific phenomenon and its relationship to other phenomena [18]. Several situations may present themselves and limit conceptual change:

- understanding the phenomenon may turn out to be too difficult [19]
- students might understand a new theory about a phenomenon, but not believe it
- they may firmly believe their initial idea to be valid and ignore some data to preserve that first opinion
- they may demonstrate little interest in the studied phenomenon [10]
- finally, members of the community where the students live can share different opinions and conceptions than those to be developed by students, holding back the learning process [9].

4 Pedagogical strategies favouring conceptual change

Several pedagogical strategies that favour conceptual change have been identified ([11,12,16,20,21] etc). Posner et al.'s conceptual change model [22] was one of the most experimented with and criticised. According to Posner et al. [22], several conditions must be met for a learner to decide to modify one of his or her conceptions. An individual must first experience dissatisfaction with the initial conception. That individual must then understand the new conception that is proposed and find it plausible. Finally, he or she must find that the new conception enriches his or her knowledge. Hewson and Thorley [23], inspired by Posner et al. [22], however clarify that in the course of the conceptual change process, the initial conception considered relevant at the beginning progressively loses its status to be replaced by a conception closer to that of accepted science. In this paradigm, the pedagogical intervention recommended to teachers mainly consists of creating a cognitive conflict in learners. The idea is to first invite students to express their ideas regarding a given phenomenon and then present them with a demonstration that counters those ideas. The resulting cognitive conflict then provokes dissatisfaction, and the remainder of the conceptual change process occurs naturally [20].

The validity of Posner et al.'s model [22] was put into question by a number of researchers during the last decade. Duit [10] contends that initial conceptions are firm, entrenched and often resist cognitive conflict. Similarly, according to Pintrich et al. [24] and Martin and Grosier [25], Posner et al.'s model [22] does not place enough importance in the learners' motivational and affective components. These researchers consider it important to emphasise the individual in its entirety. Goals, values and feelings of efficiency and control are also influential factors in the conceptual change process. Students' goals and perceptions are components that influence their commitment on the path toward the modification of conceptual structures. Finally, the classroom context influences the interaction between motivational and cognitive factors in learners. Hewson et al. [12] add that a teacher must, during the educational process, encourage the expression of a variety of ideas from different people in the class and must invite them to fully explain their ideas. The teacher must also make use of metacognition and ask students to think about the value of their ideas. Vosnianidou and Ionannides [11] also insist on the importance of this stage of metacognition in the conceptual change process, explaining that students are not always aware of the hypothetical nature of their beliefs and preconceptions. It is thus important to supply students with a learning environment that encourages the expression of their ideas and beliefs, and then to make them have significant experiences that allow them to understand the limits of those ideas and beliefs, and consequently to motivate students to revise them.

Researchers also propose other strategies designed to favour conceptual change. Experiential learning, or real contact with people and objects in the environment, is one of these. Pruneau and Lapointe [26] define experiential learning as a process through which the participants fashion their ideas and beliefs through affective and cognitive transactions with their biophysical and social environments. Bell [27] contends that experiential learning consists of a relationship between people and their environment during which a meaning is discovered. In the field of EE, Sauvé [28] explains the stages of experiential learning in the following manner. First, *concrete experimentation* is a mode of learning centred on *feeling*. During this stage, the learner is in a learning or problem-solving situation; one gains new experiences by interacting with one's environment. Secondly, *reflective observation* is centred on the act of *observing*. The learner must observe, reflect and try to understand reality from his or her experiences. Then, during *conceptualisation*, the learner *thinks about*, fashions and constructs his or her conceptions. Finally, *active experimentation* is centred on the act of *doing*. At this stage, the learner relies on his or her newfound knowledge to make decisions and solve problems. The learner also makes a transfer by experimenting that knowledge in new situations. Pruneau and Lapointe [26] add that, during reflective observation, the student can reflect alone or with a teacher on what was experienced. Furthermore, during synthesis (active experimentation), the learner can share the value of his or her experience with peers, or apply it to another context. Experiential learning thus allows students to feel different emotions such as challenge, pleasure, desire to share their impressions, amazement, compassion, etc. [26] all the while sustaining a debate about conceptions thanks to their confrontation with exterior reality and with peers that simultaneously interpret this reality [9].

Discussion is another strategy that encourages conceptual development [29]. Verbal interaction between peers allows students to verbally communicate their ideas and opinions, and thus their conceptions. Social interactions create cognitive dissonance and debate among the children, making them aware of the existence of ideas different from theirs. This contradiction can lead them to modify their initial ideas [30].

Finally, scientific writing is another strategy that helps conceptual change. Having to write down their ideas allows students to elaborate on them, evaluate and revise them. In that respect, two pedagogical methods have proven themselves: *concept mapping* (students schematically represent their ideas at each stage of the learning process) and the *dialogue journal* [31]. The dialogue journal's goal is to guide the student to a higher level of understanding and thought. The teacher, acting as collaborator rather than evaluator, formulates a problem for the student. That student writes his or her answer and immediately shows it to the teacher, who then asks another question in order to make the student's reflection evolve. There follows a back-and-forth of questions and answers between teacher and student, a process that creates a deeper reflection. Deeper reflection is another strategy that influences conceptual change [32].

This is how Posner et al.'s initial model of conceptual change [22] evolved and was developed to offer a diversity of ways to modify or broaden learners' conceptions. According to Duit and Treagust [33], it is possible to create three types of cognitive conflict: the conflict resulting from interaction with the environment, the conflict created during discussions between the teacher and the students, and finally, the one born from interactions between peers. Contact with objects and the environment, discussion with the teacher and peers, deep and metacognitive reflection, and scientific writings will help the student realise the presence of a conflict and consider the possibility of modifying his or her conceptions. The same strategies will accompany the student on his or her path toward the construction of new conceptions.

5 The pedagogical method used in the research

Inspired by the theoretical framework on conceptual change just presented, we designed a pedagogical process in four steps, a process susceptible of making young children's ideas on pollution and the relationship between pollution and health evolve:

- Make students express and explain their initial conceptions individually or as a group. Discuss, confront varying points of view.
- Go onsite or conduct experiments or research. Note the new ideas brought by the experiences.
- Present the results of scientists who made the same observations or conducted the same experiments. Compare these results to those of the group.
- Draw a conclusion based on what the students think following these various experiences and present their conclusion to people outside the class.

Through each of these steps, discussion and the dialogue journal were used. The systematic creation of cognitive conflict was also used on a few occasions.

6 The research method

6.1 The context of the Cap-Pelé village

The coastal village of Cap-Pelé harbours a community of 2000 inhabitants. Its economy is based mostly on fishing and fish transformation. Many fish factories discharge carcasses and other fish waste unsuitable for human consumption directly into the sea, quite close to sites where the citizens swim. Among the factories, thirty are smokeries, producing smoked herring and whose smoke causes significant air pollution. These two factors, combined with a smoking habit predominant among students' parents, help make Cap-Pelé a New Brunswick village where this is a high incidence of asthma in children (one child in five) and cancer in adults.

6.2 The participating group

A class of nine and ten year old students ($n = 19$) participated in the pollution and health educational process. The teacher, interested in the project, allowed a biologist and a graduate student in education to work with her students for a period of 45 minutes each week during the entire school year. The biologist and graduate student led the pedagogical activities and collected the research data (interviews with students).

6.3 Unfolding of the pedagogical process

Here is a schematic representation of the interventions conducted with students in order to make their ideas about pollution and the pollution-health relationship evolve. Throughout the process, socioconstructivist and experiential interventions succeeded each other in non-linear fashion, favouring spiral rather than linear learning.

6.3.1 Phase 1: centred on pollution

- First problem set out to students: In your opinion, are living beings (animals, plants and humans) in your environment healthy? Points of view are shared.
- Seaside fieldtrip, pictures taken of animals and plants that children think are in good and not-so-good health. Observations are shared, and pictures are classified in Healthy and Not healthy groupings.
- The biologist explains how she evaluates the health of plants and animals. Reclassification of pictures.
- Dialogue journals (teachers/students) to allow the children to reflect more deeply on what they now think of healthy animals and plants.

- Second problem set out to students: In your opinion, are there things that can affect your health in Cap-Pelé? If so, what can these things do to your health? The question is asked so as to cause cognitive conflict. A teacher disguised as a seagull makes an announcement to the children that the village of Cap-Pelé is a clean and ideal place for human and animal life. The children start to contradict that announcement. Discussion on the subject ensues.
- Fieldtrip in the environment to identify environmental hazards.
- In teams, students conduct a research on the impacts of four environmental hazards: water pollution, environmental stressors (smoke, noise, traffic…), home cleaning products, and harmful substances found in foods. Documentation is supplied for their research needs and guests come in to make presentations on the subjects. The project's biologist conducts the same research independently.
- Communication of the teams' results.
- Dialogue journals between teachers and students.
- The biologist communicates her own results to the students. Class discussion on the subject.

6.3.2 Phase 2: centred on health [34]

- Cognitive conflict: three fictional characters come into class and share with students the means by which they stay healthy. One of the characters eats well, but does too much exercise; another exercises and eats well, but doesn't sleep much, etc. Discussion as a large group to share students' conceptions of ways to stay healthy.
- With the help of health specialists (doctor, nutritionist, physical educator), students evaluate their own ways of staying healthy, then determine and experience an individual health improvement plan (sleep, nutrition, exercise). The trial period for this improvement plan is around a month.
- During this month, the village's environmental hazards are covered again, this time by asking students to collectively produce a mural representing the various types of pollution found in Cap-Pelé.

6.3.3 Phase 3: centred on the environmental action

- Students are asked to think of ways to improve elements of their environment to make them more conducive to the health of citizens. The ideas are shared.
- A specialist makes a presentation to the students on ways to improve the environment to ultimately improve health.
- The group discusses possible actions again and opts for the construction of a giant chess and checkerboard in a coastal park. The board, with pieces representing marine resources that students would like to conserve in their environment, acts as a meeting place for people of all ages in the community. The board also gives people a reason to spend time outdoors.
- Finally, the students offer their research's conclusions on Cap-Pelé's environmental situation to the town council, as well as their environmental action.

6.4 Data collection

The research's first aim was the description of students' ideas on pollution and the pollution-health relationship before any pedagogical intervention. It seemed interesting to know the related opinions and beliefs of young students living in a highly polluted area. The research's second goal was describing the evolution of students' ideas following experimentation of the experiential and socioconstructivist pedagogical process. Did the students' ideas evolve, and if so, in what way?

Drawings and semi-structured individual interviews were used to identify students' conceptions about pollution in September 2001, and then again in June 2002, following the pedagogical process. These two techniques are suggested by Thouin [18] who contends that children draw and explain things or phenomena in daily life the same way they understand them. Each child was first asked to draw what pollution was for him or her. The child then explained his or her drawing to the interviewer, who also asked open questions like: *What is pollution for you? What do you look for in a place to say it's polluted? Do you think about pollution when you're home? If so, what do you think about? etc.* For the pollution-health relationship, open questions were added to the interview guide. For example: *In Cap-Pelé, are there things in your environment that can make you sick? What, for example? What could this do to your health?* Experimentation of the interview guide was conducted with five children not participating in the research, and modified according to the results. Interview questions were the same for the initial and final evaluations, except that two questions were added to the final interview: *If you compare your September and June drawings, do you see differences? If so, what changed? Why do you think you changed your mind?* Interviews were recorded on audiocassette and transcribed for analysis.

6.5 Data analysis

Individually, two researchers (one that participated in the classroom, and professor-researcher from the University) qualitatively analysed the interviews' data through content analysis. Emergent categories were obtained based on the original interview questions, categories grouping similar conceptions in students. The two judges then compared the categories obtained. Their inter-coding percentage was 94%. The content presented in the results section represents all categories of children's conceptions that emerged in the different interviews (before and after). Conceptions are presented based on their frequency.

7 Results and discussion

Now follow tables that summarise students' ideas about pollution and the consequences of smoke and water pollution on their health, in September 2001 and June 2002 [35].

7.1 Conceptions of pollution

Table 1 presents students' conceptions of pollution. In this table, as with the tables that follow it, the different types of writing used help to classify the children's conceptions in the following manner: conceptions generally accepted by the scientific community (normal type), conceptions different from those of the scientific community (shaded type) and conceptions that are either difficult to classify or fall outside the research's context (*italic type*).

Table 1 Nine and ten year olds' conceptions of pollution in September 2001 and June 2002

Children's conceptions	*N = 19, (%)*	
	September	*June*
Trash on the ground (bags, bottles, etc.)	19 (100)	20 (100)
Trash in the water (factory waste, oil, bags, etc.)	13 (68.4)	9 (47.4)
Smoke (from houses, industry, cigarettes, cars, fires)	8 (42.1)	15 (79)
Rotten things, rot	*2 (10.5)*	*0 (0)*
Dust	2 (10.5)	2 (10.5)
Seagulls = sign of pollution	2 (10.5)	9 (47.4)
Cleaning products	1 (5.3)	2 (10.5)
You have to see the person throw out the garbage to know it's pollution	1 (5.3)	0 (0)
Pollution is everywhere, not just in the water	1 (5.3)	0 (0)
Pollution that we can't see, that makes us sick	1 (5.3)	0 (0)
Noise (loud music, car horns, trucks, tree cutting, shouts, trains)	0 (0)	7 (36.8)
A lot of garbage on the ground, not just a little	0 (0)	1 (5.3)
Grey clouds = sign of pollution	0 (0)	1 (5.3)
Can harm animals	0 (0)	7 (31.6)
Destruction of nature through tree cutting = pollution	0 (0)	2 (10.5)
Caused by non-biodegradable things	0 (0)	1 (5.3)

By looking at the September column on this table, we note that participating students, like the children questioned by Toussaint et al. [7] and Brody [8], associate pollution with visible waste found on the ground or in the water ($n = 19 + 13$). Comments such as "A boat is leaking oil. The man piloting it is throwing paper overboard." (Melissa) or "They throw their things away everywhere … cans and paper." (Sylvia) were constantly found in conversations conducted with the children. We also note, in the September column, that a few students ($n = 8$) are aware of the presence of noxious smoke in their environment. They will say: "The smoke from industries pollutes the air." (Patrice) or "The smoke from fires is pollution" (Stéphane). A few other students also supply plausible answers. To them, pollution can be invisible ($n = 1$); can be found anywhere ($n = 1$); dust is a form of pollution ($n = 2$); cleaning products are pollutants ($n = 1$); and the presence of seagulls may indicate the presence of pollution ($n = 2$). However, three other students supply more or less acceptable answers. And so, for two of the children, rot is pollution "because it stinks" (Stéphane), which more or less conforms to accepted scientific views. Similarly, one student said that we must "see someone throw the trash away" to tell that an area is polluted.

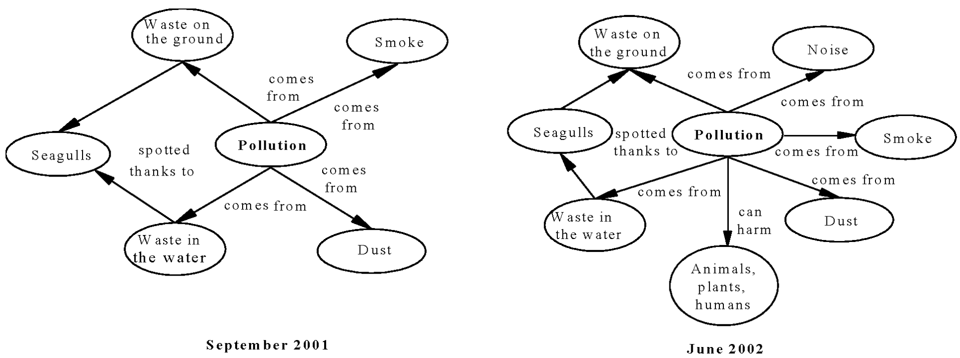
These results show that in September, the children associated pollution with visible waste in their environment. The idea of dirtiness was constantly related to that of pollution. Similarly, the children did not spontaneously evoke the effects of pollution on animal or human health.

What of their ideas about pollution in June 2002? In Table 1's June column, we first note that the number of plausible answers has increased. The children still consider pollution to be visible waste either on the ground ($n = 20$) or in the water ($n = 9$). However, the number of students aware that the smoke in their environment is a form of pollution has increased ($n = 15$). Similarly, a greater number of children associate the presence of seagulls with that of pollution ($n = 9$). Finally, seven students discovered noise pollution, and seven evoked the harmful effects of pollution on fauna and flora as well. Other plausible answers were supplied by a smaller number of students: tree cutting harms nature ($n = 1$), and non-biodegradable waste causes pollution ($n = 1$).

In June then, Hélène describes a drawing she made this way: "I drew a smokery with smoke, a car that sends smoke into the air, and a pipe coming from the smokery that's all dirty and that goes in the water." Similarly, spontaneous references to the harmful effects of pollution are more frequent: "There is pollution in water. It's dirty everywhere, and it can make us sick." (Jason); "Some people throw garbage on the ground and some in the water. Then, birds go in the water, and it kills them. (Jérémie); "If you smoke a cigarette, you lose six to ten minutes of your life" (Patricia).

To conclude on the subject of children's conceptions of pollution, we can say that they still consider pollution to be visible waste. However, they have broadened their conceptions to include harmful noises and the harmful effects of pollution on human beings and nature. According to Duit's classification [10], the operated conceptual change could be called *peripheral*: a persistence of initial conceptions, but the addition of new ideas. The following concept map (Figure 1) illustrates the conceptual change experienced by the students.

Figure 1 Concept maps representing students' ideas about pollution in September 2001 and June 2002



7.2 Students' conceptions on the effects of smoke on their health

Table 2 presents children's ideas about the effects of smoke in their environment on their health, in September 2001 and June 2002.

Table 2 Nine and ten year olds' conceptions on the effects of smoke (from industries, trucks, cigarettes, fires) on their health, in September 2001 and June 2002

Children's conceptions	*N = 19, (%)*	
	September	*June*
Asthma	3 (15.8)	10 (52.6)
Harms health, makes you sick	3 (15.8)	3 (15.8)
Breaks the circle around the Earth (layer of greenhouse gases)	1 (5.3)	0 (0)
Lung infections	2 (10.5)	0 (0)
Death	1 (5.3)	0 (0)
Cancer	1 (5.3)	2 (10.5)
Eye irritations	1 (5.3)	3 (15.8)
Hurts the nose, bad odours	1 (5.3)	0 (0)
Colds	*1 (5.3)*	*0 (0)*
Headaches	0 (0)	2 (10.5)
Nausea, vomiting	0 (0)	1 (5.3)
Allergies	0 (0)	2 (10.5)
Fainting	0 (0)	1 (5.3)
Skin irritations	0 (0)	1 (5.3)
Heart problems	0 (0)	1 (5.3)
Coughing	0 (0)	1 (5.3)
Stress	0 (0)	1 (5.3)

If the table's September and June columns are compared, we again note a broadening of children's conceptions on the effect of smoke on their health. In September 2001, the students could name only a few plausible consequences of smoke on their health. And so, Jason said: "Smoke can make my brother sick because he already has asthma." Rémi, for his part, said: "My brother … His eyes become red and when he goes to bed, he can't sleep." In June, students could name a greater number of plausible consequences of smoke on their health and were more aware of the link between smoke and the high number of asthma cases in their village. Rino explained his understanding of smoke's impact on health this way: "It can cause asthma, hurt the eyes, and cause cancer because it goes in your lungs" while Barbara said: "Smoke gives you allergies and asthma." The operated conceptual change about the effects of smoke on health is once again of a *peripheral* nature because the students retained but broadened their initial conceptions.

7.3 Students' conceptions on the effects of water pollution on their health

Table 3 presents the children's ideas about the effects of water pollution on their health, in September 2001 and June 2002.

Table 3 Nine and ten year olds' conceptions of water pollution's effects on their health, in September 2001 and June 2002

Children's conceptions	*N = 19* (%)	
	September	*June*
Poisoning	1 (5.3)	0 (0)
Headaches	1 (5.3)	4 (21.1)
Nausea, vomiting	1 (5.3)	1 (5.3)
Stomach aches	1 (5.3)	1 (5.3)
Oil in water: *Pneumonia*	*1 (5.3)*	*0 (0)*
Death	0 (0)	1 (5.3)
Earaches	0 (0)	8 (42.1)
Hazardous to health, makes sick	1 (0)	6 (31.6)
Diarrhoea	0 (0)	2 (10.5)
Fever	0 (0)	1 (5.3)
Conjunctivitis, red eyes	0 (0)	8 (41.1)
Cancer	0 (0)	3 (15.8)
Skin irritation	0 (0)	11 (57.9)
Heart problems	0 (0)	1 (5.3)
Coughing	0 (0)	1 (5.3)
Stress	0 (0)	1 (5.3)

In Table 3, we note that very few students in September 2001 knew the impacts of water pollution on their health. Six consequences were named, five of them plausible. In June 2002, however, students could each name several plausible consequences of water pollution. The most common consequences of water pollution such as skin irritation, earaches and conjunctivitis, were well retained and understood. Nonetheless, in June 2002, six students said water pollution was harmful, but still could not identify the specific effects on their health.

Here are the comments that illustrate the evolution of the children's ideas between September 2001 and June 2002:

September

- "Sometimes boats leak gas into the water and it kills fish. It can make people sick because if they do this too much, you can get pneumonia!" (Rémi)
- "Paper in the boat and that paper flies into the water. It can make us sick, and then we have to go to the hospital." (Rino)

June

- "You can get diarrhoea, fever, conjunctivitis, skin irritation." (Denis)
- "If you go swimming, you can have red eyes, you can feel sick to your stomach and vomit. Your ears can hurt because the water can go in your ears." (Mélanie)

The conceptual change obtained on the effects of water pollution on health is once again *peripheral* because the students retained but broadened their initial conceptions.

8 Conclusion

For children living in a polluted area to decide to protect themselves from environmental hazards in their milieu, either by taking care of their general state of health (through exercise and good nutrition) or by accomplishing direct and indirect [36,37] environmental actions, it is important for them to first be aware of these hazards and their effects on their health [38,39]. At the start of the intervention, the students had not yet achieved that level of awareness. To them, health hazards were to be found much closer to them, that is in their house or personal life. They would consequently more readily identify elements like sugar, fatty foods and aggressive people as harmful to their health. Examples of such answers to the question "Are there things in Cap-Pelé's environment that can be hazardous to your health?" included: "When people bug me" (Lisa), and "When I eat things like chocolate and gum and everything that's sweet" (Jason). A few seemed aware that smoke and water pollution could be hazardous to their health, but most did not know just how these environmental hazards could affect them. Some students even associated water pollution with the presence of paper products in water. So how could they imagine that this *paper* and other objects could make them sick?

In June 2002, the 19 fourth-grade students show a slightly wider vision of pollution in their environment and of the consequences this pollution has on their health. They now acknowledge that pollution can come in the form of garbage, smoke and noise, and that these types of pollution can potentially have specific impacts on their health. However, the students did not modify their conception of pollution as consisting mainly of waste perceptible to their senses: paper products, oil in water, smoke that can be seen, and noise that can be heard. According to Novak [40], conceptual change is a difficult process. The students, in order to change their conceptions, must be able to insert the new information in their previous cognitive structures, i.e. these previous structures must allow the desired construction. Thus, what we perceive of events or objects depends on what we already know, but also on our observation strategies and emotional, physical and social situation [40]. Can we say that this initial idea of visible waste is fecund enough to favour the construction of the new idea that pollution can be hazardous to one's health? After this study, we believe so. Following interventions based on observations, discussion, research, writing, reflection and idea comparison, young children seem to be able to construct the conception that pollution can be hazardous to their health, starting from the idea that pollution only constitutes visible waste. We believe experiential learning and the socioconstructivist approach, as experienced, contribute to significant learning and encourage *learning*. Indeed, Novak [40] explains that at the point where significant learning occurs, new concepts are integrated into the previous cognitive structure as long as sufficient *effort* is made to favour that integration. This significant learning is opposed to learning 'by heart' (memorisation), an approach often used in schools. We also believe that onsite observation generates motivation thanks to the cognitive conflict between children's ideas and observed reality. The proposed socioconstructivist approach encourages the *effort* required to construct new conceptions because it is not an easy experience for children, and because it attributes importance to childish ideas. Deep reflection on conceptions, explanation of conceptions, confrontation of ideas between peers, understanding of scientific texts, and the writing of dialogue journals did not appear to be easy for young children. Perhaps the effort required of these last interventions that sustain the cognitive conflict between peers' and adults' ideas favours learning better than traditional methods of information-explanation and learning by heart. As Hassard [41] would say, *hands-on* experience is not enough; we also need *minds-on* experiences.

This study offers a first information on the ideas shared by nine and ten year old students from a polluted area about pollution and the impact of certain types of pollution on their health. To these students, pollution must be visible, is mostly made up of objects thrown to the ground, and can affect people (in an undetermined way).

From these conceptions, and using the experiential and socioconstructivist approach described above, students were able to broaden their conceptions of pollution and health, but without modifying the idea of pollution as *perceptible by the senses*. It thus seems that we can make the ideas about pollution of children living in a polluted area evolve up to a certain point. Other attempts at using the proposed conceptual change process will be necessary in order to validate its content and steps in environmental and health education. The dialogue journal was a privileged tool in this experiment for students' scientific writing. Other linguistic tools, like individual concept maps, the Vee Heuristic [42,43], discussion of procedures (execution of concept maps in collaborative groups; [44]) and backing-up (active listening or peers' arguments and evaluation of the argumentation's quality; [45]) could also be used to allow students to explain their ideas verbally or in written form, as well as to gain higher awareness of these ideas.

References and Notes

1 This study was funded by the NAFEC (North American Fund for Environmental Cooperation), the EJLB Foundation, the Oracle Corporation, and the CAP (Environment Canada's Community Animation Program).

2 Landrigan, P.J., Schechter, C.B., Lipton, J.M., Fahs, M.C. and Schwartz, J. (2002) *Environmental Pollutants and Disease in American Children: Estimates of Morbidity, Mortality and Costs for Lead Poisoning, Asthma, Cancer and Developmental disabilities*, Center for Children's Health and the Environment, Website: www.childrenvironment.org.

3 Commission for Environmental Cooperation (2001) *Programme D'action nord-Américain pour 2002–2004*, North American Commission for Environmental Cooperation, Montréal, Québec.

4 World Health Organization (2002) *La santé des enfants et l'environnement*, Website: www.who.dk/London99/CHILDREN02f.htm.

5 Throughout this paper, the terms *conceptions* and *ideas* are used interchangeably to refer to children's conceptions. The definition of the term *conception* is taken from Laplante: "Conceptions correspond to the personal knowledge of individuals about certain scientific notions and phenomena. They also represent their way of thinking and reasoning when dealing with these notions and phenomena. These conceptions are often different from generally accepted scientific models" [6, p.6].

6 Laplante, B. (1998) Apprendre en sciences, c'est apprendre à «parler sciences»: des élèves de sixième apprennent à parler des réactions chimiques. Presentation at the *Congrès annuel de la Société canadienne pour l'étude de l'éducation*, Ottawa, Canada.

7 Toussaint, R., Lavigne, A., Laliberté, B., Deslierres, T. and Khanh-Thanh, T. (2001) *Apprentissage et enseignement des sciences et de la technologie au primaire*, Gaëtan Morin, Boucherville, Québec.

8 Brody, J.J. (1991) 'Understanding of pollution among 4th, 8th and 11th grade students', *Journal of Environmental Education*, Vol. 22, No. 2, pp.24–33.

9 Inagaki, K. and Hatano, G. (2002) *Young Children's Naïve Thinking About the Biological World*, Psychology Press, New York.

10 Duit, R. (1999) 'Conceptual change approaches in science education', in Schnotz, W., Vosniadou, S. and Carretero, M. (Eds.): *New Perspectives on Conceptual Change*, Pergamon, Amsterdam, pp.263–282.

11 Vosniadou. S. and Ioannides, C. (1998) 'Form conceptual development to science education: a psychological point of view', *International Journal of Science Education*, Vol. 20, No. 10, pp.1213–1230.

12 Hewson, P.W., Beeth, M.E. and Thorley, N.R. (1998) 'Teaching for conceptual change', in Fraser, B.J. and Tobin, K.G. (Eds.): *International Handbook of Science Education*, Kluwer Academic Publishers, Great Britain, pp.112–126.

13 Hallden, O. (1999) 'Conceptual change and contextualisation', in Schnotz, W., Vosniadou, S. and Carretero, M. (Eds.): *New Perspectives in Conceptual Change*, Pergamon, Amsterdam, pp.48–93.

14 Legendre defines a concept as "a mental and general representation of stable traits common to a class of directly observable objects that can be generally applied to all objects with the same characteristics" [15, p.11].

15 Legendre, R. (1988) *Dictionnaire Actuel de L'éducation*, Larousse, Paris.

16 Nersessian, N.J. (1991) 'Conceptual change in science and in science education', in Matthews, M.R. (Ed.): *History, Philosophy and Science Teaching*, Teachers College Press, Toronto, Canada, pp.119–127.

17 Di Sessa, A.A. and Sherin, B.L. (1998) 'What changes in conceptual change?', *International Journal of Science Education*, Vol. 20, No. 10, pp.1155–1191.

18 Thouin, M. (1997) *La didactique des sciences de la nature au primaire*, Éditions Multimondes, Sainte-Foy, Québec.

19 Garrison, J.W. and Bentley, M.L. (1990) 'Science education, conceptual change and breaking with everyday experience', *Studies in Philosophy and Education*, Vol. 10, pp.19–35.

20 Macbeth, D. (2000) 'On an actual apparatus for conceptual change', *Science Education*, Vol. 84, No. 2, pp.228–260.

21 Strike, A.A. and Posner, G.J. (1992) 'A revisionist theory of conceptual change', in Duschl, R.A. and Hamilton, R.J. (Eds.): *Philosophy of Science, Cognitive Psychology and Educational Theory and Practice*, State University of New York Press, Albany, NY, pp.147–176.

22 Posner, G.J., Strike, K.A., Hewson, P.W. and Gertzog, W.A. (1982) 'Accomodation of a scientific conception: toward a theory of conceptual change', *Science Education*, Vol. 66, pp.211–227.

23 Hewson, P.W. and Thorley, N.R. (1989) 'The conditions of conceptual change in the classroom', *International Journal of Science Education*, Vol. 11, pp.541–553.

24 Pintrich, P.R., Marx, R.W. and Boyle, R.A. (1993) 'Beyond cold conceptual change: the role of motivational beliefs and classroom contextual factors in the process of conceptual change', *Review of Educational Research*, Vol. 63, No. 2, pp.167–199.

25 Martin, M.L. and Grosier, S. (1994) 'Sharon's story: the usefulness of conceptual change constructs in promoting student reflection', *Journal of Science Teacher Education*, Vol. 5, No. 4, pp.139–145.

26 Pruneau, D. and Lapointe C. (2002) 'Un, deux, trois, nous irons au bois L'apprentissage expérientiel et ses applications en éducation relative à l'environnement', *Éducation et Francophonie*, Vol. 30, No. 2, Website: www.acelf.ca/revue.

27 Bell, M. (1995) 'What constitutes experience? Rethinking theoretical assumptions', in Kraft, R.J. and Kielsmeier, J. (Eds.): *Experiential Learning in Schools and Higher Education*, Kendall/Hunt, Boulder, CO, pp.9–16.

28 Sauvé, L. (1994) *Pour une Éducation Relative à L'environnement*, Guérin, Montréal, QC.

29 Driver, R. (1989) 'Student's conceptions and the learning of science', *International Journal of Science Education*, Vol. 11, pp.481–490.

30 Fleer, M. (1992)' Identifying teacher-child interaction which scaffolds scientific thinking in young children', *Science Education*, Vol. 76, No. 4, pp.373–397.

31 Reddy, M., Jacobs, P., McCrohon, C. and Herrenkohl, L.R. (1998) *Creating Scientific Communities in the Elementary Classroom*, Heinemann, Portsmouth, NH.

32 White, R.T. and Gunstone, R.F. (1989) 'Metalearning and conceptual change', *International Journal of Science Education*, Vol. 11, pp.577–586.

33 Duit, R. and Treagust, D.F. (1998) 'Learning in science from behaviourism towards social constructivism and beyond', in Fraser, B.J. and Tobin, K.G. (Eds.): *International Handbook of Science Education*, Kluwer, Grande-Bretagne, pp.3–25.

34 Phases 2 and 3 of the intervention are less centred on pollution than on health and environmental action. Indeed, the research conducted also targeted students' conceptions of their health and capacity for improving their village's situation. However, these other two parts of the research are not discussed in this paper.

35 We also questioned students about the impacts of other environmental hazards like harmful products found in foods and home cleaning products. However, the length of this paper does not allow the inclusion of these results.

36 Jensen and Schnack [37] differentiate between *direct* environmental action, where individuals participate personally to problem solving, from *indirect* environmental action, where individuals use various strategies to incite third parties to invest in ecological welfare.

37 Jensen, B.B. and Schnack, K. (1997) 'The action competence approach in environmental education', *Environmental Education Research*, Vol. 3, No. 2, pp.163–178.

38 We would like to specify that we take into consideration the fact that possessing adequate environmental knowledge does not necessarily lead to action. Other factors are also present in the process of taking action: valuing the action to be taken, a sense of solidarity, attachment to nature, prior realisation of community actions, the perceived impression that the task is easy enough to accomplish, personal rewards following the action, etc. [39].

39 Pruneau, D., Chouinard, O., Musafiri, J.P. and IsaBelle, C. (2000) 'Les facteurs qui influencent le désir d'action environnementale dans les communautés', *Revue des Sciences de L'éducation*, Vol. 26, No. 2, pp.395–413.

40 Novak, J.D. (2002) 'Meaningful learning: the essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners', *Science Education*, Vol. 86, pp.548–571.

41 Hassard, J. (1992) 'Research in science education: post, present and future', in Gräber, M., Komarek, A. and Reiska, S.P. (Eds.): *Minds on Science*, Harper Collins, New York, pp.64–97.

42 The Vee Heuristic consists in asking students to represent in a great V each step of the construction of their conceptions from their world vision, personal theories and previous conceptions to their new conceptions, interpretation and generalisation, including operations and observations made to get these results [43].

43 Novak, J.D. and Gowin, D.B. (1984) *Learning How to Learn*, Cambridge University Press, Cambridge.

44 Wellington, J. and Osborn, J. (2001) *Language and Literacy in Science Education*, Open University Press, Buckinghan, UK.

45 Wells, G. and Chang Wells, G.L. (1992) *Constructing Knowledge Together: Classrooms as Centers Of Inquiry and Literacy*, Heinemann, Porsmouth, NH.