How scientists and students pose an environmental problem

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ABSTRACT

With the help of scientists, young students tried to solve the problem of sedimentation in a watershed. Researchers observed how the students and the scientists **posed** the environmental problem. Problem **posing** consists in determining the characteristics of the problem, the desired situation, in summarizing the problem and in using adequate external representations. Students represented the problem with drawings and annotated drawings while scientists wrote short sentences. Students and scientists considered many causes and impacts of the problem. Scientists looked at the problem abstractly, not specifying its exact location in the watershed and the responsible players. Many of the students' solutions were normative while scientists' solutions were more realistic. Scientists thought about possible barriers to actions. Some students were concerned about the impacts on animals, but scientists thought about the long-term impacts on humans. Pedagogical strategies are suggested to improve students' and scientists' capacities to **pose** an environmental problem.

INTRODUCTION

In sustainable development, *human capital* is defined as the presence of active, creative, and highly engaged members in a community. Human capital, once inventoried, consolidated, and wisely used, can lead a community to social, economic and ecological prosperity [1]. Young people are part of this capital, which is to be taken into account and reinforced in a community striving for a sustainable pattern of living. To facilitate the full participation of youth in the sustainable development of their community, they need to develop creative environmental problem solving skills [2].

Chawla [3] reports that while being involved in educational projects, children of different ages proposed some effective solutions to local environmental problems. However, environmental problems are not easy to solve, considering their complexity (they include people, locations, politics, impacts, causes, etc.,), their dynamics (they develop in space and time), and their multidisciplinary nature [4]. What are the young's real capacities to solve environmental problems? How do the young's capacities differ from the scientists'? Very few researchers described these capacities in young people and scientists [5].

Our team is particularly interested in the way the young and the scientists **pose** an environmental problem, after having studied it and been asked to find solutions. This article describes how 8 years old students and scientists **pose** an environmental problem. First of all, we will present a theoretical framework on problem **posing**, based on domains of creativity and science education. Then, we will describe the contexts in which we have performed problem solving experiments with students and scientists, and the research's methodological tools. We will then report and analyse the results and finish with a discussion on pedagogical strategies that could be used to improve children's capacities to **pose** environmental problems.

POSING AND SOLVING PROBLEMS

Problem solving consists in looking for a way to reduce the gap between an initial, non-satisfactory situation and a desired situation [6]. Problem solving could be summarized as an initial situation, a desired situation, and a series of operations allowing development towards a solution. The *cyclic* process of problem solving usually develops in eight principal operations: finding a problem, **posing** a problem, finding solutions, assessing and choosing solutions, planning the action, acting, evaluating the action and the experienced process. Problem **posing** plays a crucial role among these operations. Advantages of accurate problem **posing** are the following: getting an exact idea of what we are looking for, recognizing pertinent information more easily, reducing the initial feeling of disorientation facing a new situation, and providing efficient solutions [7].

Posing a problem first consists in formulating it in order to better solve it [7]. During this operation the person interprets the problem situation in her own words, *rearranges* information related to the problem, reformulates repeatedly the problem in order to clarify it and represents obstacles to the action and goals to achieve. **Posing** a problem is a difficult task. To **pose** a problem, an individual must be able to use his knowledge, associate his ideas, think, make abstractions, monitor, investigate, evaluate and visualize. He must be able to identify a variety of problem characteristics, to choose words to determine the actual and the desired situation, and to repeatedly summarize the problem in one sentence [8]. Thus, while ***posing*** a problem, people synthesize, simplify and organize information regarding the problem [9]. They decode its linguistic and mathematical elements, and represent it in a form favourable to solving it, establishing links between problem elements (causes, places, impacts, obstacles…), and their previous knowledge [10]. The problem is thus re-created by people.

Problem **posing** is being carried out on numerous occasions during the problem solving process. Figure 1 illustrates how our research team sees the *Problem posing* operation, within the problem solving process.

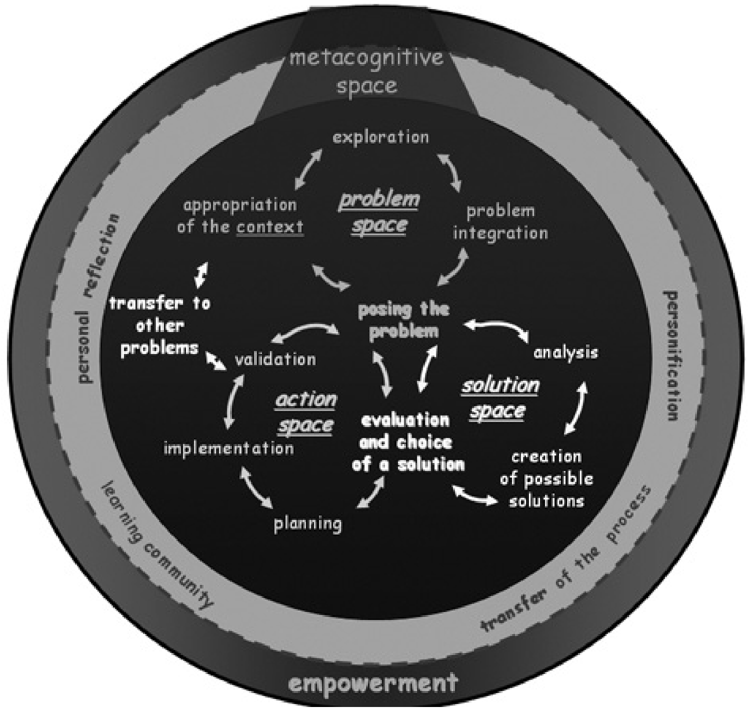

Figure 1. Representation of the problem solving process [2]

In figure 1, problem solving is presented as a cyclic process, involving constant back and forth movements between problem space, solution space and action space. Faced with a situation, the individual perceives the presence of a problem. He explores the problem, reflects, investigates and formulates the problem in its different dimensions. This allows him to generate solutions and to choose one of them, which he will apply after having planned the action. Throughout this process, the individual constantly goes back and forth between the various operations. When he discovers new aspects of the problem, he returns to the problem space and reformulates the statement. If he doesn't find many solutions, he re-poses the problem. If he realises that the chosen action is not feasible, he looks for other solutions.

Varied factors influence the individual's ability to better **pose** a problem: motivation to solve it, capacities to persevere and to reason deeply, past experiences with similar problems and enriched knowledge of the problem domain. The person must also be able to use various efficient *heuristics* for problem analysis [11]. *Heuristics* are different means used to better define a complex problem, this being the case with environmental problems. These heuristics include varied external representations in visual, textual, or symbolic forms. These representations are used to visualise the important ideas of the problem (the initial state), links between ideas, the actions to execute, potential restrictions in these actions, the goals to reach, and the importance of the problem in one's personal life. These external representations are also beneficial when the amount of information related to the problem exceeds the ability of the short-term memory. Other heuristics can also be beneficial: immediate testing of possible solutions, working backwards (finding solutions to worsen the problem), dividing the problem in many small tasks and finding solutions for each of them, etc. [12].

Research in chemistry and biology problem solving mostly consisted in comparisons between the abilities of experts and those of beginners. They reveal that experts are more successful in problem solving because of their wide knowledge of the field and because they spend more time on **posing** the problem [5]. Experts more often use drawings and diagrams to represent the problem, better consider qualitative details, make more connections between the elements and more adequate connections, and take advantage of analogies. Experts' knowledge is cognitively better structured and therefore more accessible. Experts also discern more easily missing information in solving the problem. Finally, experts' more developed metacognitive abilities allow them to plan and monitor their approach to the problem. Beginners also use drawings and diagrams but their representations are often incomplete and include errors because of their lack of knowledge of the problem's domain. Beginners experience difficulties in determining the most important characteristics of the problem [5]. Beginners go straight (towards a solution) more often, while experts move their attention back-forward and forward-back, constantly testing their solutions, and checking up with the goals of problem solving.

To our knowledge, students' and environmental scientists' abilities to **pose** environmental problems have not yet been described by researchers. Some research has focused on students' conceptions of unfamiliar problems [13] but nothing was said about the abilities of students and scientists who studied a problem and were asked to solve it.

METHODOLOGY

During an entire school year, a class of Grade 3 students in Canada was involved in solving a local environmental problem. With the scientists' help, students studied impacts of sedimentation on the Cocagne watershed's animals. Sedimentation consists of soil elements and plant debris moved from their original position by water and wind, and then dropped into the water stream. Several human activities such as clear cutting and use of ATVs may increase its quantity. Sedimentation has many negative impacts on fish and invertebrates.

The students experienced a socio-constructivist approach that put them in the centre of teaching-learning process making them active and reflective investigators, all process being reinforced by the children's discussion. The students made onsite observations analysing the river and identifying the problem in its real-life context. The participating scientists chose the sedimentation problem because sedimentation was thought to be an important problem in the studied watershed. Once the problem was identified, the students analysed it in-depth using field observations, questioning, data collection and analysis. During the school year, a teacher from our team conducted 50-minute weekly interventions in the classroom and in the field. Scientists participating in the project came to the classroom and to the field three times during this process. Their pedagogical task consisted in collecting, with students, scientific data on the problem, analysing this data and explaining their results to students. For their part, the students looked for information on the problem and shared their findings and ideas with the scientists. This collaborative approach allowed children to explore all aspects of the problem: causes, impacts, places, etc. From February, students were regularly invited to list solutions to the problem, and some representation strategies were used to help them consider several aspects of the problem and share their points of view: construction and presentation of a model on sedimentation, as well as collaborative realisation of schematics, texts and drawings about the problem. Finally, they chose and applied a solution: participation in a radio show to address the topic.

At the end of the project, in June, we observed how the students **posed** the problem with a questionnaire and individual interviews. All the students answered the questionnaire in which they had to represent individually the studied problem, to express their feelings regarding the problem, and to propose and justify several solutions. Individual interviews followed the questionnaire, during which the students explained their problem representation and answers.

The four participating scientists all had a degree in science: a diploma of collegiate studies in ecology, a Bachelor in biology or a Masters degree in environmental studies. They all had occasion to observe the sedimentation in the Cocagne watershed, without however conducting a thorough study of it. The same data collection tools (questionnaire and interviews) were used with the scientists five months after the experimentation at school. This delay is due to the scientists' non-availability before this time.

The data of the questionnaire and interviews was subjected to a qualitative analysis. Based on the elaborated theoretical framework, **three judges** first considered the following data elements: problem's elements mentioned by students and scientists (causes, impacts, places, players…), types of external representations (visual, written, schematic…), concerns about the problem and types of solutions proposed. Tables presenting main themes found in the data were prepared for the class and the scientists.

RESULTS

Types of representations used by students and scientists

Most students represented the problem with drawings or annotated drawings. Some students added short texts to their drawing. They justified their choice of drawing with the fact that it was the best way to understand the problem and explain it to others. Most scientists wrote short sentences to describe the different aspects of the problem. Figure 2 shows an example of Grade 3 students' typical representations when **posing** the sedimentation problem. The young author includes herself in the drawing and writes that sediments are soil carried to the river because of clear-cutting and use of ATVs.

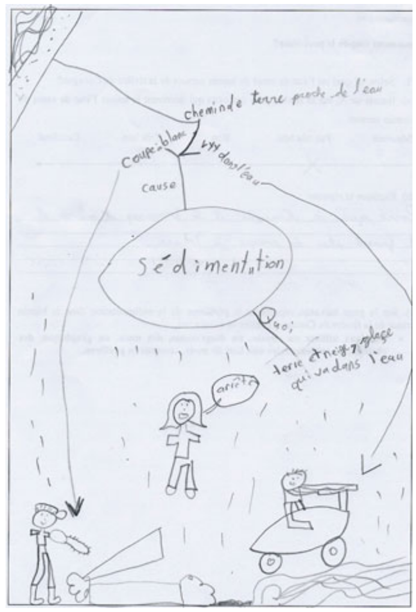

Figure 2. Drawing by a 3rd grade student (after eight-month study of sedimentation)

Elements of the problem considered by students and scientists

Tables 1-4 show the elements of the sedimentation problem included in the representations and remarks of students and scientists when they posed it.

Table 1. Details linked to the problem itself, considered by students and scientists

Problem details	Students (n = 20)	Scientists (n = 4)
Sedimentation worse with heavy rain or snow	0	1
Presence indicator: brown water	3	4
Worse if sediment quantity is high	0	1
Increased by climate changes (heavy precipitations, storms…)	0	1
Presence indicator: increased turbidity	0	4

Table 2: Causes considered by students and scientists

Causes	Students (n = 20	Scientists (n = 4)
ATVs, tractors, motorcycles, clear-cutting machinery	19	3
Natural causes: rain, snow, water, ice, wind	16	4

Road construction near water, dirt roads	13	3
Excessive clear-cutting near water	17	4
Livestock with free access to the river	9	1
Canal construction near water	1	2
Population uneducated about problem	0	3

Table 3: Impacts considered by students and scientists

Impacts	Students (n = 20)	Scientists (n = 4)
Death of fish	7	2
Reduction of fish vision	10	1
Destruction of fish habitats	3	2
Impacts on fish eggs	2	4
Impact on fish gills	3	2
Impacts on humans: Make them sick, less seafood and fish to eat, drinking water full of sediment	6	4
Reduced river depth	0	2
Contamination of milieu if there are toxins in sediment	0	2
Impact on water: turbidity, quality…	1	2
Impact on aquatic insects	0	2
Buries molluscs and reduces their capacity to filter food	0	3

Table 4. Obstacles to the problem’s resolution considered by students and scientists

Obstacles to the problem’s resolution	Students (n = 20)	Scientists (n = 4)
Sedimentation = a complex, abstract problem not well understood or recognized	0	3
Improbable participation of the government	0	2

Future increase of human population	0	1

Our data shows that despite different backgrounds and experiences related to sedimentation, many young learners can get some valuable insights into key elements of the problem, its causes and possible impacts. For example, if we take into account the ratios, about the same number of children as environmentally educated adults consider such causes as natural events, use of ATVs, clear-cutting and road construction. Regarding impacts of the problem, scientists show a much deeper understanding, mentioning impacts on fish, humans, invertebrates, and quality and depth of water. Students are less convinced about humans (mentioned by 6 children of 20) or fish (10 of 20 mentioned impacts on vision). The difference could be explained by the fact that while different causes can be seen onsite or on pictures, the impacts (like human health or damaged fish eggs) are too abstract and require a construction of more complex logical chains. Not surprisingly, children most often mention limited vision in fish because they relate it to the observation of the colour of the sediment-filled water (brown). Maybe scientists' more developed environmental knowledge allows them to visualize what is going on under the water with species and sedimentation. In Table 3, we can finally note that the impacts of sedimentation mentioned by participants vary according to each participant and that no single person can consider them all at the same time.

In Table 1, we also notice that scientists are the only ones to bring up some of the more specific aspects of sedimentation, such as its quantitative (the problem worsens if quantity increases), temporal (the problem may worsen in the future) and circumstantial (heavy rain worsens the problem) dimensions. Scientists also have at their disposal two indicators (brown colour and turbidity of the water) to recognize the presence of sedimentation, while the three students use only the *brown water* indicator.

In Table 4, we may note that only scientists mention obstacles to the sedimentation problem's resolution. Perhaps the capacity to analyze actions' repercussions goes beyond the abilities of youth cognitively situated at a concrete stage of reflection. Eight-year-old children also lack the metacognitive level for evaluating that the sedimentation problem is an abstract and complex one to solve.

Three other tables should have been presented as part of these results: Players; places with sedimentation problems; and desired situations following the problem's resolution. However, neither students nor scientists precisely indicated where they found sedimentation in the Cocagne watershed. Similarly, no participant clearly indicated people or types of people that provoked sedimentation. What can explain the absence of consideration for sedimentation places and players? As scientists greatly influenced the information transmitted to students, the reasons explaining this absence perhaps lie with the scientists. Two hypotheses may be formulated. Scientists may not have known where sedimentation is found in the Cocagne watershed because they did not sufficiently monitor the site. Or environmental scientists have a tendency to analyze the problem theoretically, from descriptions and solutions found in books, without however regularly going onsite to observe and analyze its social aspects, i.e. the players responsible for the problem, and the interests and needs that motivate these players. The study object, i.e. the environment, is thus analyzed in offices rather than onsite and with an emphasis on more scientific than social aspects. If this hypothesis is true, the solutions suggested by scientists might neglect the social dimension of environmental problems. Finally, the desired situation following the problem's resolution was only mentioned by one scientist whose goal is to reduce the quantity of sediments in the river.

Students' and scientists' concerns regarding the studied problem

At the beginning of the project, students seemed surprised to be invited to find solutions. They did not realize that they would really take action to improve the problem. At the end of the project, seven students (n=20) said that they were worried about the health of animals, but most of the students were not really preoccupied, which may explain by their belief that sedimentation has few impacts on humans and thus, on their own lives. On the other hand, the problem worried scientists, perhaps because of their greater ability to foresee human impacts or their marked sensibility to animal welfare.

Nature of solutions proposed by students and scientists

Table 5 presents students' and scientists' proposed solutions to the sedimentation problem.

Table 5. **Solutions proposed by students and scientists**

Proposed solutions	**20 students**	**4 scientists**
Do not drive ATVs, motorcycles or tractors in the water	18	1
Do not cut trees near river	19	1
Educated people by showing them numbers, pictures, posters, films, through letters to the editor or in school…	15	4
Stop construction of roads near water	13	2
Replant near rivers	6	4
Do not overturn the ground or cut trees when it rains	0	3
Cover gardens and new lawn with vegetables in winter	0	2
Ask the government to improve roads	0	2

Find the sources of sedimentation	0	2
Build bridges for ATVs	0	2
Prevent livestock from reaching the river	9	1
Buffer zone between agricultural fields, new lawns, roads, and the river	0	2

Our data lets us to assume that a variety of problem representations does not necessarily lead schoolchildren to a variety of solutions. While the 4 scientists proposed 21 different solutions, the 20 children comparatively limited themselves to 6 solutions, the most popular being *do not cut trees, do not drive ATVs* (19 and 18 children of 20). Both of these solutions were barely mentioned by scientists (1 of 4). While all four scientists proposed planting plants as solutions, only 6 children of 20 mentioned it. The only solution popular with both groups was educating other people (all 4 scientists and 15 of 20 children). We also notice that many students' solutions are of a normative type. The solutions of the *not doing something* type proposed by students may demonstrate their conviction that others are better equipped than them to solve the problem. These ideas could also be more obvious to children experiencing more often several *'not to do so'* rules regulating their everyday behaviour. The scientists' solutions may reflect better factual knowledge and professional experience: build bridges for ATVs, buffer zones, etc.

The scientists, on the other hand, offer few new or original solutions, that seem to be borrowed from books rather than adapted to Cocagne's reality. Since the players and places related to sedimentation were not identified by both groups of participants, the solutions remain generic with little thought to their possible success.

SUMMARY OF THE RESULTS

In light of our theoretical framework, can we tell that the participating students and scientists **pose** an environmental problem adequately? Scientists and students consider many varied causes and impacts of the sedimentation problem. The scientists take into account slightly more of the problem's causes and impacts than the children do. Only the scientists discuss certain details and obstacles to action. Places and responsible players are however under-considered by both groups. The resolution of real problems process, though recommended in Canadian school programs, still seems to be applied very little in schools and students demonstrate limited reflective, critical and creative thinking habits. As for the scientists, perhaps their training has not prepared them to **pose** environmental problems in a complete way, or to propose original solutions.

PEDAGOGICAL STRATEGIES FOR IMPROVING STUDENTS' AND SCIENTISTS SKILLS

Based on these results, we might recommend more regular exchanges between scientists and students, and a more sustained involvement by scientists as part of an actual problem resolution process. This work could be facilitated by visual representation tools and exchanges such as *Participative Mapping* (home-made map of an area and of the problem, [14]). In the field of creativity, other problem representation tools are available, i.e. the *Fish Bone Diagram* (problem represented as a fish with bones representing causes, [15]), the Circle of Opportunities (diagram in the form of a clock; students write a problem aspect under each number, [8])… Green [16] affirms that a problem can be examined in more visual detail (with the help of pictures, diagrams, illustrations), verbally (with words, sounds, sentences), digitally (with numbers to specify the extent or importance of the problem), sequentially (with representation of development stages), conceptually (with the help of symbols, theories, and analogies), and emotionally (expressing feelings and opinions regarding the situation). Therefore, it would be relevant to take advantage of these strategies in order to help students complete their representation of the problem.

Student's ability to **pose** a problem could also be improved by teaching them some metacognitive strategies used by experts. For example, they could be taught to summarize the problem several times in the form of a question taking into account the *desired situation*. Michalko [8] suggests that the problem formulation be started with: *How could I…* The students could also be provided with a list of strategies used by the participating scientists to better analyse the problem (consult the Internet, look for numbers to quantify the problem, observe pictures, find solutions proposed by others…). Students could try the metacognitive strategies they prefer, share their discoveries, their new way of posing the problem and enrich their representation at the same time.

Does students' and scientists' way of **posing** the problem allow them to generate creative solutions? Both groups' solutions are generally unoriginal. In order to help young people and scientists succeed in the whole process of creative environmental problem solving, we will also have to study their ability to successfully execute the other operations of the process, i.e. find creative solutions, choose an adequate solution, etc. These other abilities could be developed or reinforced in people. More research is also necessary, with other scientists, students of different ages, and on the resolution of other environmental problems, to validate the results and hypotheses presented in this article.

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