Under the Direction of Diane Pruneau

# Design Thinking for a Sustainable

Applied Models for Schools, Universities and Communities

# Design Thinking for

# Sustainable Development

## Applied Models for Schools, Universities and Communities

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**Cover page:** These images show various environmental problem solving projects with adults and young people.

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# Introduction

Sustainable development is defined as development that meets the needs of the present, while safeguarding the systems that support life on Earth, upon which the survival of current and future generations depends (Griggs et al., 2013). The meaning of sustainable development and the actions that assure its achievement are beginning to emerge in many places on the planet (Norberg and Cumming, 2008). Recent sustainability initiatives include *Slow food* (Petrini, 2006), *Conservation Design* (Arendt, 1996), *Smart Growth* (Duany et al., 2010), ecological cities (Register, 2006), the banishment of harmful products (Maniates, 2010), the restoration of biodiversity (Fuller et al., 2010, Foreman, 2004), *Sustainable Happiness* (O'Brien, 2012), *Assisted Migrations* (McLachland et al., 2007).), etc. *Slow food* practitioners take the time to share healthy local food with people in their community. In *Conservation Design*, urban planners develop new neighborhoods, initially identifying the natural and cultural resources found there, and then locate buildings so as to protect the environment in which these resources are found. Proponents of *Smart growth* and ecocities use a variety of techniques to absorb or reuse rainwater, slow down car traffic, densify inhabited areas, or promote universal access to parks. The ban on harmful products seeks to prohibit the sale of products harmful to health or the sale of goods made from endangered species. Steps to restore biodiversity are varied: wildlife crossings, green walls, green roofs, ecolodges for specific species (insects, amphibians, small mammals, etc.) and other infrastructures. Sustainable happiness, as conceived by O'Brien (2012), is characterized by the thoughtful and critical choice of lifestyles conducive to the health and quality of human life and ecosystems. Finally, through assisted migration, species threatened by climate change or habitats are carefully moved to help them migrate to more favorable locations.

Through these sustainability initiatives, physical systems, practices and physical layouts are altered from what existed beforehand (Pruneau et al., 2014, Wals, 2010). Success in carrying out these projects is ensured by leaders who share a specific skill: creativity (Pruneau et al., 2013). Indeed, taking risks, embracing change, uncertainty and complexity (Montuori, 2012), demonstrating an empathetic understanding of what others are experiencing and how environmental events affect them and seeking to imagine how things might be different and facing up to current and future challenges, all require healthy doses of imagination and creativity (Pruneau et al., 2014). These creative leaders also demonstrate independent thinking; they know how to identify problems and take risks (Robinson, 2001) and to develop innovative, effective and achievable solutions (Torrance, 2008).

Could it be possible, through educational activities, to help people be creative enough to change the environment and the practices that shape its nature and health? How can groups of students or citizens be pedagogically supported while they analyze local problems, propose, test and implement solutions? In this regard, several international organizations are currently applying a creative problem-solving approach called *design thinking.* This process is defined as a creative and collaborative way of working in which intuition matters, solutions are numerous, experimentation happens quickly, failures are considered as learning and, above all, where the needs of users are taken into account (Brown 2009, Liedtka and Ogilvie 2011, Lockwood 2010). Since its formal creation by IDEO, in 2006, design thinking, adopted by many companies, has enabled the creation of original products: ICTs (including the mouse for Apple computers) and tools for science and engineering. IDEO has also inspired the development of many similar approaches: the Innovation Lab, Strategic Design, Transformative Design, Human-Centered Design ... In fact, even if design thinking was initially used for creating commercial products, it is now used for the benefit of humankind and the environment. In movements such as *Design for Life* and *Human-Centered Design* (Buchanan, 2001, Irwin, 2000: Thakker, 2012), and organizations such as *IDEO.org*; d.school (Stanford University); *MindLab* and *INDEX* (Denmark); and *Hasso Plattner Institute* (Germany), life-friendly practices are now being developed. The positive transformation of the environment and humanitarian action are currently at the heart of design.

First of all, this paper presents the approach to design thinking as understood and mastered by 20 international organizations who have adopted it as a work tool and a means of changing the world as we now know it. For example, INDEX has fostered the creation of a system for ridding the oceans of plastic waste: the Ocean Cleanup, which uses floating gates placed in ocean currents to capture floating plastic debris.


***1.1 Ocean Cleanup* (INDEX)**

In this paper, the 20 organizations whose expertise is presented on design thinking all seek to develop a product, service or experience that improves the lives of people in ordinary or vulnerable communities. Some of these organizations call upon their own employees to find solutions to local problems, while others take on challenges in collaboration with students or community groups, making design thinking a relevant educational tool. To better understand the strategies and tools that these 20 organizations identify as steps towards success in implementing design thinking, their websites and *Facebook* groups were examined; and efforts were made to gain insight to their point of view through interviews or questionnaires.

In addition, this paper defines and explains design thinking by explaining its beginnings, its use by particular organizations and its use as a teaching tool. This approach is compared with other approaches that can be used in teaching to solve problems related to science, technology, and the environment. It also examines various factors that participating organizations consider a means of achieving success: the types of teams and the work atmosphere that should be fostered, the strategies to use at each step, the collaborative digital tools (ICTs) that can facilitate the process, the equipment and layout of the premises, and the evaluation of the products of design thinking. Finally, through narratives that set out a diversity of experiments in varying contexts and environments, the authors will examine how young students put design thinking into practice, while working together with future teachers, future engineers and community groups. Ideas for environmental issues that need to be solved and the documentary resources necessary to do so are suggested for readers who would like to dig deeper into this fascinating process.

# Chapter 1

# 1. Design thinking: what is it?

**Diane Pruneau, Boutaina El Jai, Liliane Dionne, Natacha Louis, and Patrice Potvin**

## 1.1 Definitions

The concept of design thinking was pioneered, primarily, by Tim Brown and David Kelley, the founders of the design and innovation firm IDEO, one of the first design agencies that appeared in the United States. Design thinking is a human-centered approach that relies on innovation, collaboration, and creativity to solve a multitude of social and environmental issues (IDEO.org, 2012). As a creative and analytical approach, it is an amalgam of concepts in engineering, design, the arts, social sciences, and business. Design thinking is also defined as "collective intelligence", whereby core consideration is given to the human being, human behaviours and needs and wherein creativity among participants frequently challenges previously suggested solutions.

Design thinking fosters the use of the designer's sensitivity and methods for solving complex problems. In fact, designers are used to confronting complex problems by generating numerous solutions that they test to gradually improve upon them. Working within a rigorous framework, using well-defined tools, while fluctuating between divergence and convergence, design thinking uses both creative and analytical modes of reasoning (Lietdka, 2014).

## 1.2 Steps of design thinking

Design thinking happens in definite and non-linear stages, where back-and-forth actions (iteration) intersect, with the ultimate intent of bringing about transformative change. The steps set out below (see Figure 1) were inspired by Brown (2009) and Scheer, Noweski and Meinel (2012).

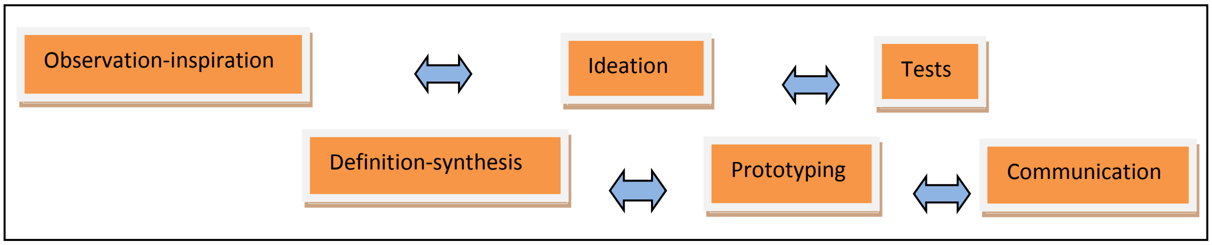


**Figure 1. The steps of design thinking.**

Diagram inspired by Brown (2009) and Scheer, Noweski and Meinel (2012)

1. *Observation-inspiration*: an ethnographic survey is conducted while demonstrating true empathy for the situation, so as to understand the people affected by the issue (the users) and the problem they are experiencing. Users are observed daily to gain insight into their aspirations and needs.
2. *Definition-synthesis*: the problem is defined repeatedly and in numerous ways. The objective is to seek information and various perspectives on the issue. The information is briefly summarized in order to present the problem in only a few statements, often through the use of visual aids. The visualization of the concepts directs the problem solvers towards a common goal (the conceptual challenge) and promotes a common understanding of the goal among participants.
3. *Ideation*: many ideas are proposed and some of them are chosen.
4. *Prototyping*: prototypes are quickly built to emphasize the ideas that have been generated, to share them with others and to assess their potential.
5. *Tests*: prototypes are evaluated by collecting opinions from users and experts. Winning prototypes are then refined (Scheer, Noweski and Meinel, 2012).
6. *Communication*: development of the product is revealed (Brown, 2009).

Design thinking is not solely an activity that involves artistic creation; it is a rigorous process undertaken by problem solvers who seek to understand the goals, experience and constraints of users. Design thinking seeks to define the technical and strategic parameters of a design challenge, and to craft and develop solutions. Among the 20 organizations whose work was examined, several variations appear in the implementation of the various stages of design thinking.

## 1.3 Characteristics of design thinking

Design thinking is an iterative approach, focused on the needs of users, while remaining practical and flexible in terms of trial and error. The approach focuses on empathy and user optimism. It is simultaneously inductive, deductive and abductive.

**An iterative approach**

Both divergent and convergent in nature, the process of design thinking is centered on human need. Design thinking is not linear, since the attention of the problem solvers flows between the problem-space and the solution-space, while empathy for users needs grows and while the winning solution undergoes refinement.

Compared to traditional scientific investigative approaches, design thinking concerns itself as much with the problem as it does with the solution. In the problem-space, great importance is attached to defining the problem according to the experience, point of view and situation of the user. The team of problem solvers spends a lot of time observing the situation-problem and the behavior of users *in situ*. Deepening and building insight into the problem is essential to the efficiency of the process. In the solution space, solvers seek a multitude of alternative leads by developing plans and shaping prototypes. Prototypes made quickly and without regard to perfection act as "playgrounds" for discussing and learning about certain solutions (Liedtka, 2014). Thus, the problem and the solutions co-evolve in constant interaction.

**An approach centered on user needs**

For INDEX, the user is defined as the "target clientele", that is to say, one which is negatively affected by a given situation and who will benefit directly from the solution. Users are always at the center of the design process. The team of problem solvers tries to find a solution that meets user needs and improves their quality of life. IDEO.org insists on the importance of knowing and understanding users, because it is only by examining the situation or the problem from their perspective that a significant and lasting solution can emerge. Thus, constant and constructive user feedback is essential throughout the process; it allows solutions to evolve and apply directly to peoples' needs and expectations. Thanks to this iteration, initial ideas are refined and improved upon so as to generate new ideas. New approaches stem from the practice and foster creative thinking. Solutions are therefore more numerous and creative, and they enjoy greater success upon implementation.

**An empathetic approach**

Empathy, in this case, refers to compassion. It is the "ability to intuitively take the place of the other, to feel the same as him, to identify with him". For IDEO.org, this attitude helps to understand what people experience in difficult situations. Empathy that allows problem solvers to truly grasp the context of a situation, allowing for the development of a solution focused on the needs of the people involved. Problem solvers must therefore observe the needs, desires, motivations, frustrations, difficulties and objectives of users. Empathy allows one to put aside assumptions and to consider experiences through the eyes of another.

There is a difference between emotional empathy and cognitive empathy. The first provides insight into user emotions and the latter allows for an in-depth examination of their initial experience with the issue and their perception of the proposed prototypes.

**A concrete approach**

Ideas for solutions must be firmed up quickly. In order to allow for their assessment, abstract ideas are constantly changed into tangible ones, thus enabling insight into their potential use and limitations. These prototypes make it possible to explore the solution space. They can be digital, physical prototypes or they can take the form of graphs. The prototypes are then tested with the users and restructured several times.

**An optimistic approach**

This approach values optimism for both the people who use it and for users, a mindset which is necessary in order to tackle complex issues such as poverty or climate change. Facilitators and problem solvers must believe in the value of progress, be open to all possibilities, and demonstrate resilience in the face of challenges.

**An approach that values trial-and-error**

Whether during *Ideation*, *Prototyping* or Implementation, the failures experienced during design thinking provide problem solvers with considerable knowledge. The goal in this case is not to immediately come up with a perfect solution, such that no further editing is required. It is necessary to constantly rework and improve upon an idea in order to better meet the needs of others. Dealing with obstacles and failures is a guarantor of success.

**An approach that is inductive, deductive and abductive**

Traditional scientific inquiry uses inductive and deductive thinking to solve specific problems, such as searching for the position of a star at a given time. The inductive approach begins with observations that lead to a hypothesis or a scientific model. It is a process of generalization that begins with the observation of particular cases. The deductive approach begins with hypotheses that are then applied to a particular case. The researcher starts with the hypothesis of a relationship between different variables and then applies it to the examination of a certain number of observations. In the traditional, positivist scientific investigation, problem solvers distance themselves from the subject of their inquiry in order to ensure the greatest possible level of objectivity. On the other hand, in attempting to solve complex problems, such as determining the means of adapting to climate change, the use of another type of thinking is preferable: abductive thinking. This type of thinking involves considering ideas, products or services that, once put into use, could indeed work. Design thinking, the approach in which problem solvers immerse themselves in the environment of the subject under review, calls into play inductive, deductive and abductive thinking all at the same time. This approach would therefore be particularly useful in situations characterized by uncertainty. To summarize, design thinking is an approach where problem solvers, facilitators, and users work together in a spirit of collaboration.

## 1.4 Origins of design thinking

Design thinking was developed within the framework of theoretical and practical research, both in the humanities and sciences, to meet contemporary human and technical requirements. Engineers, business people, scientists, and creative individuals have always tried to understand the processes of innovation. It was towards the end of the Second

World War, as people were looking for ways to solve complex problems that design thinking gradually emerged.

From the fifties to the seventies, several authors worked as forerunners in design thinking. In 1952, the publicist Alex Osborn promoted the technique of brainstorming, introducing the world to creative thinking. Later, in 1965, technologist Buckminster Fuller introduced the "scientification" of design, opening up the rational world of science to creativity. In 1969, cognitive sciences specialist Herbert Simon spoke of rapid prototyping and repetitive testing, reconciling engineering and creativity.

Beginning in the 80s, the use of design thinking began in various professions. Robert H. McKim (1980), a mechanical engineer who relied on creative strategies, came up with the idea of "visual thinking", that is to say using visual representations (drawings, diagrams) as a way of framing problems and solutions. The idea of setting problems and solutions aside, and thinking about something else, before coming back to them later is an idea that originated with McKim, among others. The architect Nigel Cross (1982), who observed the problem-solving methods of various professions, concluded that many architects, engineers, and planners demonstrate good problem-solving skills when they chose to generate a large number of solutions, before eliminating those that were considered to be less effective.

For his part, Horst Rittel (1984), a design theorist, developed the concept of the "wicked problems" to designate problems that were complex and multidimensional in nature. He proposed a collaborative form of design whose process included a thorough understanding of humans. There was also the creation of an interdepartmental program at Stanford University, called "Product Design", a human-centered program. In 1987, Peter Rowe, Harvard's Director of Urban Design Programs, published his book *Design Thinking*, in which he described the survey method used by architects to perform a complex task.

The nineties saw design thinking become more complex and widely accessible. In 1991, in Palo Alto, California, David Kelley and Tim Brown founded the IDEO Design Agency, which defines, explains, and popularizes design thinking, as developed at the

Stanford Design School. Carnegie Mellon University's Director of the Design Department, Richard Buchanan (1992), published his article, *Wicked Problems in Design Thinking*, in which he explained how the sciences, which have been developing since the Renaissance and formalized in various specializations, have been cut off from one other. He explains that design thinking represents an opportunity to integrate specialized scientific fields so that they come together as a means of solving current problems from a holistic perspective.

Since the beginning of the 2000s, design thinking has continued to develop throughout the world. Starting with the approach brought forth by IDEO’s Timothy Brown, design thinking - as a problem-solving approach relevant to numerous academic disciplines and diverse situations – has caught the eye of academics, management firms, governments and humanitarian agencies concerned with finding innovative solutions to current problems. Focused on user needs, the approach proposed by Brown (2009) has become central to the search for solutions to human and environmental problems.

With the founding of the *Hasso Plattner Institute School of Design Thinking* in Germany, a joint research program on the impacts and methods of design thinking (the d.school) is being launched in collaboration with Stanford University in California. Since the beginning of this program, there has been a proliferation of publications, seminars and courses on design thinking in the world's leading universities.

## 1.5 Organizations interviewed and examples of achievements

Around the world, companies and educational and humanitarian organizations are now opting for design thinking to effectively deal with human and environmental problems. This approach allows them to find new ways of seeing problems and finding solutions, since ambiguous problems are often difficult to solve using traditional methods. Because these issues involve multiple challenges and a variety of participants, and require consideration using different approaches, an approach such as design thinking contributes to the development of effective and sustainable solutions.

In preparing this guide, the authors considered 20 active and successful international organizations focused on human-centered design thinking.

The authors first of all compiled information on the content of their websites and their *Facebook* pages. Then, they either conducted interviews with representatives of these organizations or asked them to answer a questionnaire, or had them do both. The results of their study revealed that some important and pioneering organizations have always favored and encouraged development and research over design thinking. The following organizations come to mind:

- d.school Institute of Design at Stanford University (USA);
- Hasso Plattner Institute (Germany);
- IDEO.org (USA);
- INDEX: Design to improve life (Denmark);
- MindLab (Denmark).

Other organizations, though less prestigious but nonetheless just as productive, dedicate their efforts and use their expertise to promote design thinking and to adapt it to education, all the while coming up with solutions to community problems in collaboration with learners. The following organizations highlight that approach:

- Aardvark Design Labs (San Francisco, USA);
- Consulting Design Ltda (Santiago, Chili);
- Design for Change (Ahmedabad, India);
- Designathon Works (Amsterdam, Netherlands);
- Evangelische Schule Berlin Zentrum (Education Innovation Lab) (Berlin, Germany);
- Evergreen School (Seattle, USA);
- Franklin Road Academy (Nashville,  USA);
- Henry Ford Learning Institute (Detroit,  USA);
- KIDmob (San Francisco,  USA);
- Mount Vernon Institute for Innovation (Atlanta,  USA);
- Punahou School (Honolulu,  USA) ;
- Riverdale Country School (New York);
- Sacred Heart School (Saratoga, USA);
- St Aidan’s Anglican Girls School (Corinda, Australia);
- Workshop Education (Hillsborough, California, USA).

Together with their employees or participating citizens and learners, these organizations have created products, experiences or practices that enhance the quality of human life. For example, the IDEO.org team created the *d.light*, a solar lighting device that allows millions of poor people without electricity to enjoy night-time lighting to allow for study, play or work.

***1.2 d.light*** **(IDEO)**

Another example of a product designed to meet the needs of users in developing countries is the brainchild of students from the d.school (Institute of Design Stanford University. These students invented the *Embrace Warmer*, an incubator that can save the lives of premature newborns in India. Premature newborns have difficulty regulating their body temperature; therefore, to ensure their well being, they must be kept in an environment with a set temperature. In developing countries, incubators are often too expensive, unavailable or there is no electricity to run them. The *Embrace Warmer* looks like a small sleeping bag, with wax compartments in a pouch on the back. When boiling water is poured over the wax, the bag stays at the desired temperature for eight hours, allowing the premature newborn to stay warm.

***1.3 Embrace Warmer*** **(d.school; Stanford University)**

As for young students who have used design, those who worked with *KIDmob* are worthy of note. Their project sought to identify the needs of passersby on Market Street in San Francisco. To get people in the community to engage in more physical activity and to socialize more, the students prototyped and created an obstacle course suitable for people of all ages.

***1.4 Market Street* (KIDmob)**

And then, using the *Bamboo-zled* project, adolescents in Bhutan were concerned about the muddy, steep and slippery slope they used to get to school. Through the implementation of *Design for Change*, the students brought their parents and community together to clean the thoroughfare and surround it with a bamboo safety fence.


***1.5 Bamboo-zled* (Design for Change)**

The map displayed at **https://www.designthinkinginschools.com/** gives the reader a geographical idea of where the main organizations referenced in this guide are located. Appendix 1 also lists the goals of the 20 participating organizations, as well as the contact information for their website.

## 1.6 Design thinking applied to education

When used to solve problems with learners of all ages, especially with children at the primary level, design thinking can provide rich learning opportunities in a collaborative, effective and accessible environment (Brown, 2009). This approach is intended to support problem solvers in solving complex and wicked problems from socio-constructivist and holistic perspectives (Scheer, Nowesky and Meinel, 2012). Numerous studies have highlighted the positive effects of design thinking on learning, motivation, engagement, and creativity (Cassim 2013, Rauth et al., 2010, Renard 2014). In fact, design thinking can be used to address issues that students face in their daily lives. By targeting the interests of students and drawing on their experiences, design thinking can improve teacher-student relationships, in that it encourages active student involvement (IDEO, 2012). The practical use of design thinking in everyday life and its application in diverse situations could enhance learning experiences and make them more motivating.

Further, through the use of this approach learners can become agents of change, building trust in their creative abilities, while experiencing meaningful learning (Brown, 2009, Rauth et al., 2010). Organizations interviewed during our research also pointed to other educational benefits, especially with respect to teamwork. These benefits include, among other things, enhanced discussions because of the diversity of problem solvers, improved communication within the group, a shared understanding of the vocabulary used and greater cohesion within the group.

In an ever-changing world and in the context of globalization and rapid technological progress, human life is becoming more and more complex. Because of this growing complexity, artistic, linguistic, mathematical and scientific skills no longer suffice to enable today's youth to develop their full potential. In order for them to become active and connected citizens of the world while taking part in the building of sustainable societies that are sensitive to human and environmental issues, learners must acquire a multitude of skills, most of which are part of the 21st-century skills framework (Scheer, Nowesky and Meinel, 2012). These skills include solving complex problems, innovation, teamwork, critical thinking, communication, systemic and prospective thinking and technological skills (Pruneau et al., 2013). The iterative and encompassing process of design thinking effectively requires the use of several competencies; it requires learners to ask questions, seek out information, collaborate with their peers and the community, to propose concrete ideas, to test and model solutions, all the while taking into account user needs. This approach therefore has the potential to develop many 21st century skills among students.

## 1.7 Design thinking and the teaching of science and technology at the primary level in Canada

In Canada, science and technology programs at the primary level (from kindergarten to the year before high school) present an ideal environment for integrating design thinking. Indeed, these programs already promote various approaches to scientific investigation and since design thinking is considered an investigative process, teachers could indeed put it to good use.

Since the early 1960s, scientific inquiry has been at the heart of science education in North America (Hasni, Belletête and Potvin, 2018). The investigative approach is based on the work of Dewey (1910), who is behind this important reform in science education. Investigation refers to strategies that encourage students to discover or build information on their own, rather than having the teacher pass the information along (Duran and Duran, 2004). A teacher who puts investigative approaches at the core of her teaching strategies can be more effective in promoting learning and understanding among her students. However, it should not be assumed that investigative approaches are sufficient to ensure the building of scientific and technological knowledge and the development of scientific literacy among students. From a Bachelardian perspective, it is important to cultivate a scientific spirit among children to allow them to clearly formulate their questions and not simply state trivial opinions on scientific issues (Bachelard, 2004). In fact, true learning only occurs when learners frame problems correctly (Popper, 1985).

In addition to the formulation of questions and the use of problematization (Orange, 2012), some other criteria underpin the effectiveness of teaching practices in science and technology. In the course of some recent research, some inspiring practices in elementary science and technology were selected and reviewed (Dionne et al., in press, Dionne, Couture and Savoie-Zajc, 2007). An empirical two-year review, involving two learning communities, one in Quebec and the other in Ontario, found that other criteria, in addition to investigation and questioning, were at the heart of effective teaching in science and technology. Including investigation and questioning, these criteria are: stimulating and usual content in everyday student life, active learning, sharing and debating conflicting ideas, multiple ways of presenting information (eg ICT), conceptual enrichment, establishing a connection with community resources and a formative evaluation that helps build knowledge (see: **http://www.TableauST.ca**). These criteria meet several objectives of the Canadian provincial framework programs, as well as the results of recent research in the teaching of science (Couture et al., 2015).

With respect to the investigative approaches that color the direction of the Canadian framework in teaching science and technology at the elementary level, the analysis of some of these approaches[1] shows that two principal investigative approaches are suggested:

1. The survey approach (experimental or non-experimental): This is a socio-constructivist learning process, starting with questioning and ending with the contribution of parts of an answer to a scientific question, either through experimentation or through the collection of information;

2. The technological design approach (or technological problem-solving approach): This is a process leading to the development of a product, experience or structure to improve or provide a solution to the problem situation.

In conducting a *non-experimental survey*, students must learn to identify and critique their sources of information. For instance, students could be asked to identify the environmental and human impacts of oil sands development by obtaining information from reliable sources. During an *experimental* procedure, the exercise could mean identifying the variables involved in growing plants, by examining the influence of various substrates and abiotic factors (air, light, water). During the experimental process,

[1] Ontario, Quebec and New Brunswick Framework Programs.

students try to answer a scientific question by applying what is primarily an experimental scheme. This sometimes involves keeping a set of specifications, making observations and conducting tests, taking action, analyzing variables and recording data that will then be interpreted and reported. Whether using the experimental approach or conducting a literature review, students are encouraged to better understand the world around them by using observation, questioning, and the use of mathematical, scientific and technological language (Québec-MELS, 2001). At the same time, they get a grasp on the concepts and build their knowledge through observation, experimentation or analysis.

In technological design (or the process of solving technological problems), the second step of the programs framework, students are asked to design objects or solutions to meet human or environmental needs. For example, it could mean designing a hand-operated device to help people with mobility problems pick up objects on the ground. The steps in the current science program design approach are: identifying the challenge, researching multiple solutions, planning and building a prototype, testing and evaluating the prototype, and communicating results and procedures. Thus, the problems that students face require that they create prototype solutions by being creative and, through trial and error, that they determine if their objectives or solutions actually work.


***1.6 Kindergarten students created bird feeders (Littoral et Vie)***

The authors believe that of the two previously discussed investigative approaches, the technological design approach is the one that could be enhanced through the use of methods and tools specific to design thinking. During the stages of technological design, students must carefully plan their strategy, choose their tools and materials, create and modify their prototypes, and communicate the solutions they have chosen to implement. This approach is closer to design thinking, but it does not feature user surveys.

Although this approach is used in elementary science teaching programs in most provinces, it appears that teachers use it ineffectively or too little (Pruneau and Dionne, 2018). The authors believe that the technological design approach in the framework programs could be enhanced through the adoption of a more systemic perspective, using design thinking. By giving science students the chance to solve problems using design thinking, they would quickly feel swept up in a reflexive and collaborative process focussing on further questioning, *Ideation*, testing prototypes, and evaluating solutions. As a result, this approach would encourage cognitive and emotional development among learners and have them commit to finding solutions to the social and environmental problems that surround and affect them (Brown, 2009). Design thinking could serve as a dynamic platform for finding new ways to improve and invigorate natural and built heritage.

The quest to find solutions to climate change, problems with drinking water, urban transport, housing sustainability and handling waste could be the focus of the design. Design thinking could spark teacher enthusiasm in that it would allow them – as it does students - to explore complex social, scientific and environmental issues (Koh et al., 2015) from an interdisciplinary perspective.

What makes design thinking so powerful is its emphasis on empathy. The search for solutions is based on user interviews conducted before and after prototyping. Therefore, in conjunction with the steps it presents, design thinking would help develop many skills among students, including empathy and sociability, skills related to everyday life, as well as critical thinking, creativity, cooperation, and technological skills (if ICTs are used). The authors feel that the first step in the *Observation-inspiration* phase, where students gain an in-depth understanding of peoples' needs, could be used to develop their social skills and empathy. The *Synthesis* stage would call upon the use of their critical thinking and ability to summarize.

At the *Ideation* stage, students would feel inspired by the challenge to come up with multiple solutions. In *Prototyping*, students would demonstrate certain design and engineering skills, when asked to produce objects or draw sketches simulating proposed solutions. Finally, during the *Testing* stage, the students would put their critical thinking skills to work by evaluating and perfecting their prototypes. Because these steps are done in collaboration with peers, collaborative skills would also be acquired (Scheer, Noweski and Meinel, 2012).

However, consideration must be given to the challenges that design thinking raises in the classroom. When compared with the traditional technological design approach, design thinking requires a greater number of class periods. For example, students would require three or four fifty-minute periods to complete the technological design of paper or cardboard sandals that would provide a 3cm clearance off the ground during a three-meter walk. On the other hand, the design of a pair of sandals for older people with swelling of the feet could easily require double the amount of classroom time. Similarly, students' design of an insect shelter could take up to six or eight science periods.

In the application of design thinking, the observation phases (understanding the problem from the user's point of view) and the *Synthesis* stage (posing the problem) take some time; these steps are often dealt with quickly when other investigative techniques are used. The test phase also takes longer when applying design thinking, because it involves the evaluation of prototypes, in consultation with users. Covering these steps with users is unique to design thinking because it is not part of experimental or technological design approaches. In fact, design thinking is engineering thinking, with a strong humanistic perspective. This thinking has the advantage of being similar to the STEM (Science-Technologies-Engineering-Mathematics) or STEAM (Science-Techno-Engineering-Arts-Mathematics) movements in Canadian science and technology programs. Future reforms would be welcome in order to promote the integration of design thinking into provincial science and technology curricula at the elementary level.

## 1.8 Design thinking for sustainable development

The authors believe that designing sustainable solutions is akin to a community conversation and learning about "how to participate appropriately in the changing processes of life-sustaining that we are part of and on which our future depends" (Wahl, 2016). The design thinking approach presented in this guide seeks to introduce concrete solutions as a means of contributing towards the achievement of one or more of the 17 sustainable development goals, as defined by the United Nations, for 2015-2030. These 17 goals can be summarized as follows: eliminating poverty; ensuring access for all to adequate supplies of food, health, quality education, gender equality, clean water, reliable and affordable energy, decent work, safe and sturdy places to live; promoting shared economic growth, encouraging innovation in industry, advocating for peaceful societies and sustainable modes of consumption and production; taking urgent action to combat climate change; and taking steps to ensure terrestrial and aquatic ecosystems (United Nations, 2015).

These promising goals already inspire the development of innovative solutions in education, governance, industry, transportation, agriculture, infrastructure, energy systems, health systems, and so on. Here, by category, are the solutions that are currently implemented as well as examples for each category. Some of the solutions set out here are complex and require particular expertise. On the other hand, other solutions are within reach for young people and even primary school pupils.

Category 1: **Improving the well being and income of people, regardless of their country of origin and gender**

Examples of solutions: consuming foods that combat cancer; ICT training for women in developing countries; micro-credit; universal access to places conducive to physical activity; recovering leftover food for poor families.

Category 2: **Increasing the number of natural amenities for sustainable use**

Examples of solutions: oyster reefs (cement structures designed to reinstate oyster populations in marine environments); insect shelters; plant walls; the micro flowering of tree stands and vacant lots.

Category 3: **Removing pollutants from water, air, and soil**

Examples of solutions: the reuse of plastic bottles to make jewellery; raising chickens to eat leftovers; composting; measures to slow down urban traffic.

Category 4: **Conserving ecological and cultural biodiversity**

Examples of solutions: building shelters for bats or small wildlife (squirrels, hares); developing material dispensers (wool, twigs) for bird nests; green roofs; wildlife paths on or under highways.

Category 5**: Saving or recovering natural resources for long-term use**

Examples of solutions: sharing manufactured goods (baby items, clothing toys, sporting goods); community composting.

Category 6**: Regenerating natural resources and their resilience**

Examples of solutions: soil or swamp reconstruction.

Category 7: **Adapting the environment to contribute to the health and social, ecological and economic well being of communities**

Examples of solutions: the development of neighborhoods with limited access for cars, where a large percentage of the land mass is reserved for greenery, where rainwater is collected and where use is made of renewable energies.

Category 8: **Using the ecological benefits provided by natural resources**

Examples of solutions: $CO^2$ capture in legumes; phytoremediation (using the cleaning properties of plants to detoxify the interior of buildings); rain gardens.

Category 9: **Using nature as a design template**

Example of a solution: biomimicry (bio-inspiration): taking inspiration from naturally occurring solutions produced through billions of years of evolution to address problems in society. For example, the ultra-rapid Shinkansen train in Japan is designed to make less noise and its aerodynamic design, shaped like a kingfisher with an elongated beak, silently fishing.

Category 10: **Implementing measures to handle disasters (climate change and others)** Examples of solutions: planting trees that resist drought or heavy rainfall; greening riparian buffer strips (to reduce sedimentation in rivers or to absorb floodwaters).

Being mindful of these categories and solutions, the authors propose a human-centred design thinking model that also takes the environment into account. In so doing, problem solvers consider not only human well being, but also that of all living beings with whom humans share space. The users of solutions couched in design thinking would no longer be limited to imagining solutions solely from the human perspective, since these solutions would also prove beneficial to animals, plants, water, soil, and the air. Solutions would meet human needs, while enhancing the natural and built environments where-humans are born, grow and thrive.

The challenge of finding beneficial solutions for both humankind and the environment is a significant one. However, the authors believe that design thinking holds great promise since it takes into account the scientific and social aspects of environmental issues. However, in applying this model, it would be appropriate to have problem solvers think specifically about the benefits of solutions for other living beings and to consider the impact of the proposed solutions in the short and long term. For example, the design of a biodiverse hedge between planting rows serves to improve crop yields, attract insects and birds and also, it serves to enrich the soil and the aesthetic appeal of the countryside, all of which have an impact on the health of rural populations.

# Chapter 2

# Factors which foster the success of design thinking

**Boutaina El Jai, Diane Pruneau, Nicole LeBlanc, Natacha Louis, Isabelle Pineault**

This section will examine some of the factors that, in the view of the 20 organizations interviewed for this guide, promote success in the design thinking process.

## 2.1 Work teams

Design thinking is a collaborative approach to problem solving that requires a team effort to build effective solutions. The quality of the teams of problem solvers is essential in order for them to work properly. Several factors must be taken into consideration, starting with the number of people on the teams. In order to make coordination and decision-making easier, it is best to put together small teams. According to IDEO, teams of four work well. Team members must also have various experiences and skills related to the issue under review. Multidisciplinary teams allow for complementary perspectives on issues and team members can each assume various duties. Similarly, it is important to bring together creative people and positive-minded leaders as a means of fostering creativity and collaboration in the quest for better results (Sarin and McDermott, 2003). Putting together an ideal team of thinkers, decision-makers and "doers" requires flexibility and openness to change, since initial planning will evolve as the project moves along.

## 2.2 Setting the right atmosphere

During the iterative stage of the process, moderators must assume the roles of guides and facilitators by encouraging knowledge sharing, collaboration, reflection, communication, and empathy (Plattner, Meinel and Leifer, 2016, Liedtka, 2015). Rauth et al., 2010; Brown, 2009). At each step, they must make available the resources and tools necessary for learning and developing the team and ideas.

The work must be carried out in an empathetic, fun and friendly environment. Facilitators must believe in participants' abilities to generate creative ideas and build trust among users. This confidence is absolutely necessary to ensure the subsequent adoption of the solution put forth by the team of problem solvers. Facilitators must also encourage problem solvers to set aside any preconceived notions and have them focus on the stated goals. In addition, they must insist on open communication and authentic relationships among users by sharing updates and successes in the design process. Similarly, since design thinking is an iterative approach, facilitators must ask teams to refine and improve on the ideas that are proposed. Finally, problem solvers must be encouraged to accept failure, since trial-and-error is part of the whole process. Failure must be seen as a learning tool that allows for the improvement of ideas.

## 2.3 Teaching strategies for each step

In their quest to achieve success in design thinking and to foster innovation, the organizations we interviewed focussed on specific strategies at the various stages of the process.

**Step 1**: During the *Observation-inspiration* stage, listening to users and observing the problem situation are encouraged. Questions must also be raised. The goal here is to understand the needs of users and to define the issue at hand. Starting the process with a solution already in mind must be avoided, because it may not meet the real needs of users.

*2.1 Source image : Pixabay*

At the *Observation-inspiration* stage, numerous strategies are available. Here are a few:

- *Transfer your learning*: this strategy consists of sharing what problem solvers already know about the problem. In a discussion circle, each member shares their knowledge and jots down any new information on sticky notes, which are then sorted and displayed on the wall.
- *In-depth research*: here, to better identify and understand the issue, members investigate books, internet documents, and speak with experts.
- *Identification of users*: team members make a list of persons who have a stake in the problem and the solution.
- *Individual interviews*: the team sets up individual interviews with users. The questions are carefully prepared in advance, and the solvers note exactly what users relate as opposed to noting what they think the users meant to say.

- Starting the interview with general open questions is recommended, before getting into more specific questions that directly relate to the issue. It is important at this point to adopt a humble attitude, to carefully listen to people, to take note of nonverbal cues and the prevailing atmosphere, and to demonstrate a genuine sense of curiosity. An explanatory video on this technique is available at **http://www.designkit.org/methods/2.**
- *The Five Whys*: During interviews, the team can use the "Five Whys" technique of starting up the interview with an open question, and proceeding thereafter by repeating the "why" question five times to gain a deeper understanding of the initial answer.
- *What? How? Why?:* When considering the "*What*?" question, note should be taken of what users do and what happens around them. The use of adjectives is recommended when describing the "*What*?. In the case of the "*How*?" question, attention should be lent to how users do what they do (the task at hand). Do they put much effort into it? Is the task undertaken cheerfully? ... When using "*Why*?, the focus should be on the causes of the actions observed and the emotions which users appear to experience.
- *Expert Interviews:* the team can question experts to gain insight into their realistic, credible and context-specific perspectives.
- *Group interview*: this type of interview helps the design team to better understand a given group's sense of community and it allows for the targeting of relevant users with whom they can engage in a more probing reflection during future activities. At least two members of the design team must participate in the group interview with users.
- *Peer observation*: In this scenario, users observe their environment in order to provide the team with information on the context, the situation and the quality of life of the people among them. It is important to provide users with the tools they need to collect data (camera, recorder, etc.) and accompany them throughout the process.
- *Immersion:* This is a field trip guided by one or more users. This step is important since it allows the team to learn about the people affected by the problem as well as the circumstances surrounding the problem itself. Photographing and documenting all relevant elements of the trip is recommended.


2.2 Source image : Pixabay

**Step 2**: *Synthesis* provides an opportunity to prepare a brief summary of the issue and to provide multiple potential solutions to the matter under review. The team shares what it has learned after analyzing a great deal of data, allowing them to accurately define the conceptual challenge it faces.

Possible strategies are as follows:

- *Transfer your learning*: using sticky notes, the team shares the most relevant data collected from users throughout the course of the first step. In a circle, members take turns sharing what they have selected from the data and each of them uses sticky notes to display the new information they have learned. An explanatory video on this technique is available at: **http://www.designkit.org/methods/12.**

- *Find the themes*: Sticky notes are then sorted into categories and displayed on the wall. The idea is to identify key themes and turn them into design possibilities. Next, team members attempt to determine whether there is a particular relationship or structure among the categories. Several discussions may ensue at this stage. An explanatory video on this technique is available at: **http://www.designkit.org/methods/5.**

- *How could one ..?*: Here, the conceptual challenge is expressed clearly and precisely by voicing, on several occasions, the interrogative form of: "How could one ..? ". Example: *How could one ensure the absorption of surplus greenhouse gases*?

After asking, "*How could one?*" several times, the team asks in respect of each of the conceptual issues questions such the following: *Does putting the problem this way increase the likelihood of producing a variety of solutions? Does this approach take into account the context and user needs?* Coming up with three challenges and choosing one to use is recommended.

An explanatory video on this technique is available at: **http://www.designkit.org/methods/33**.

- *Journey Map*: This is a visual representation that relates the user's experience in relation to the issue under review, while highlighting their needs. The information collected during the first stage of the process is used to create the visual representation that summarizes the users' experiences in relation to the problem. It is therefore important to validate the *Journey Map* with users and get their feedback so as to better define the problem.

- *Empathy map*: this is a visual representation using four quadrants detailing what users say (*Say*); what they do (*Do*); what they think (*Think*) and what they can feel (*Feel*), in relation to the problem.

- *Creating stories*: here, the team tells stories that summarize the user's experience in the face of problem situations.

- *Bodystorming*: in this exercise, the team uses props to play out a daily situation that users have experienced.

- *Quotes*: quotes from interviews are displayed along with user photos to illustrate their most frequent needs.

- *Profiles*: information is gathered on users (age, civil status, patterns, needs ...) and personality types are created for various users and noted on cue cards, using readily available information.

**Step 3:** During the Ideation stage, several ideas are set out for consideration: some are kept and others are dismissed. Ideas that are retained move on to the *Prototyping* stage.


***2.3 Source image : Pixabay***

Here are some helpful strategies that can be used for this step:

- *Brainstorming*: the idea here is not to find the perfect idea, but rather to come up with several ideas in the spirit of collaboration and openness. The best way to discover good ideas is to throw out a lot of them for selection. During *Brainstorming*, the moderator plays an important role in ensuring the creation of favourable conditions, asking questions and ensuring the flow of discussion among all participants. He constantly reminds participants of the conceptual challenge they face. He puts a large white sheet on the wall where the problem is set out using the "*How could one ...?"* approach. He then explains the seven rules of *Brainstorming*: avoiding judgment, expressing and explaining all ideas, encouraging extravagant ideas, relying on the ideas set out by others, sticking to the subject, being visual, and banking on the number of solutions. Towards the end of *Brainstorming* stage, each member individually writes down on sticky notes what he considers to be three relevant thoughts and then sticks them to the wall. An explanatory video on this technique is available at: **http://www.designkit.org/methods/28**.

- *Pack of ideas*: sticky notes from the brainstorming stage are sorted into categories and displayed on a wall. The goal here is to group together the best parts of several ideas in order to produce more complex concepts. Among the categories set out for consideration are those that could constitute viable, realistic and sustainable solutions. A subsequent vote among participants will determine which solutions are promising enough to undergo further refinement.
- *Top Five*: this strategy allows participants to take a step back and give greater thought to the issue, and to work as a team to single out the five best ideas or themes generated up to that point. The authors recommend keeping the top five ideas that have been displayed in order to highlight the evolution of the project and to maintain a focus on priorities.
- *Visual thinking*: in this case, drawings, sculptures or structural plans are used to stimulate innovative solutions.

At the end of the *Ideation* stage, the design team finishes with one, two or three ideas that all meet user needs; those ideas will be prototyped at a later point.

**Step 4:** *Prototyping* or the rapid building of prototypes using paper, felt pens, glue, scissors or a computer ... allows the team to come up with a concrete idea of the solutions and improve upon them. The goal here is to transform the initial solutions into minimally functional and viable

***2.4 Source image : Pixabay***

results.

The sharing of prototypes among users is done as quickly as possible, in order to get their feedback and make changes thereto, as required. Since it is live, this step is very important since it allows for a quick and effective improvement to the solution or solutions under review.

- *Draw it:* Drawing is an important tool for expression, inspiration, and sharing. An explanatory video on this technique can be found at: **http://www.designkit.org/methods/49**.


***2.5 Source image : Pixabay***

**Step 5**: The *Testing* stage involves the practical implementation of the prototype in order for users to experiment with it themselves and for the solution to become culturally appropriate and relevant. Users can assess the benefits the prototype brings, its strengths, its deficiencies, its ease of implementation, etc.

Here are some possible strategies that can be used at this stage:

- *Measuring and Evaluating:* when the solution is on the verge of being implemented in a community, the team must determine whether it has the desired impact on those affected by the problem. The evaluation can make use of quantitative tools (questionnaires, surveys ...) and qualitative tools (conversations, interviews, phone calls ...). The team can also seek input from experts, organizations and key stakeholders.
- *Live Prototyping*: a suitable place must be chosen (kiosk, public place ...) to test the solution in real world conditions, for a period of a few days to a few weeks. An explanatory video on this technique is available at: **http://www.designkit.org/methods/18**.
- *Feedback Capture Grid*: in this exercise, a blank page must be divided into four quadrants, which are filled in using feedback from the team and users. (Quadrant 1: positive aspects of the prototype, Quadrant 2: constructive feedback, Quadrant 3: remaining questions, and Quadrant 4: ideas flowing from the discussion).

**Step 6:** During the *Communication* stage, the team reviews the work done up to that point to date and shares the final solution with the general public.

***2.6 Source image : Pixabay***

- *The pitch (pitch):* this is a great way to relay information on the solution, how it works, how it helps, what it contributes and who benefits from it. It is important to clarify the key elements of the solution and to choose how to communicate their characteristics and uses. The new solution can be presented using different formats: flyers, websites, books, presentations, videos... At this point, the solution needs to be described bearing in mind the target audience and presenting arguments in favour of its implementation.
- *The vision map*: at this point, the potential use of the devised product, experiment or service needs to be depicted on a map, using simple symbols. This map illustrates the situation as it was (when the problem was present) and where the solution intends to lead. Problem solvers and users can draw this map together or individually.

Thus, in applying design thinking, users are at the center of the entire process. The design team considers user needs, experiences ideas, and challenges before, during and after the development of a product or solution. Feedback from these users allows for the reformulation of plans until improvements to the solution are found.

## 2.4 Digital tools (ICT) that can make the process a little easier

Different collaborative digital tools (ICT) can be used during the various stages of design thinking. According to the 20 organizations canvassed in this project, the use of digital tools is not essential, but it can sometimes facilitate and support the design. In response to the conceptual challenges presented throughout the process, the organizations interviewed favoured the use of discussions with users and the use of the drawings, pencils, and papers to highlight, illustrate and to concretize creative ideas. If digital tools are used during the process, facilitators should weigh the advantages and disadvantages of the time and effort they need to access selected ICTs.

Computers, tablets, and smartphones are obviously useful for finding information, keeping in touch with team members, and sharing updates and results. The cameras and phones can be used to document field visits, record individual and group interviews, and to take pictures and videos. Computers and the Internet may also be used to conduct research on the issue under review, as well as to prepare correspondence and to draft visual depictions.

According to the NGOs interviewed and the research the team conducted, specific collaborative digital tools can also complement various stages of the process, whether they are used in person or remotely.

**Steps 1, 2 and 3** (*Observation-inspiration*, *Synthesis*, *Ideation*)**:** ICTs used for conceptual renderings such as *RealTimeBoard*, *Popplet*, *Google Slides*, *Concept Board*, *Adobe Thread*, *Coggle.it* or *Trello* can be used to synthesize user needs, together with *Stormboard*, which proposes the use of table models to sort out answers to questions such as *What, Why, Where, How, Who ...?* The same collaborative digital tools can also serve to represent the team's solutions and sub-solutions, depending on the various conceptual challenges that are presented. For its part, *Facebook* allows for the sharing of information on a problem, as well as the development and assessment of a team's solutions (El Jai et al., 2017).

**Step 4** (*Prototyping*): *In-Vision, Tinkercad, Sketch, Adobe Creative Suite, iDroo, SecondLife* and 3D Printers can all be used to create prototypes. As for *Loomio*, a collaborative decision-making tool, it is possible to discuss various ideas and choose the ones that hold the most promise (Pruneau and Langis, 2015).

**Step 5** (Testing): *Facebook* allows for the planning of the *Testing* process and the sharing of prototypes for review by the team and users (Pruneau et al., 2016). *Wrike*, a planning tool, allows for the listing and assignment of duties and for the projected completion dates of the project's *Testing* phase (Pruneau and Langis, 2015).

**Step 6** (*Communication*): *Glogster* and *Madmag* propose interesting possibilities through the use of graphs, images, and videos to highlight the end result of the design process (Pruneau and Langis, 2015).

## 2.5 Potential work materials and workspace layout

Generally speaking, materials to be used are simple and readily available. Sticky notes and felt pens are constantly used to highlight ideas, questions, and comments. When engaging in prototyping, paper, cardboard, paint and glue are mainly used to encourage team creativity. The choice of materials depends on the needs of the design team, the context of the problem under review and the proposed solution. The work environment is fundamental to the development of ideas. It has an impact on the productivity, satisfaction, and behavior of participants. This environment may include movable tables and work boards, open spaces and places for relaxation and teamwork.

Workspaces must allow for bonding among participants and they should promote a positive experience. The notion of collectivity must therefore take precedence over the individual experience (Choose and Work, 2017). It is interesting to note that it is not aesthetic appeal and wide opened spaces that are considered to be factors in creativity among individuals. Rather, creativity depends on the spatial organization of workspaces (alternating between common and private workspaces), proximity to colleagues, access to resources and places to confer.

## 2.6 Assessing the experience

The evaluation of design thinking consists primarily of assessing the product, service or experience that has been generated. The assessment of the creativity involved in coming up with solutions can be conducted using criteria relating to fluidity (a large number of proposed solutions), flexibility (emergence of various types of solutions) and applicability (impacts of the solutions on users' lives and the possibility of conducting an assessment in the context of the problem itself). In design thinking, applicability can be ascertained by counting the number of people using the product or service, or who are actively involved in the new experience. The exercise may also consist of comparing how users did things before and after the process. It is also possible to observe the impact of the new product or service. According to INDEX, the assessment of an approach involves the consideration of three elements: form, impact, and context. The form and function of the solution are then evaluated. This involves evaluating the surface, the materials, the colors, the consistency, the aesthetics, etc. However, this criterion can never be the only one assessed. When assessing impact, the criterion focuses on the importance and potential of the solution. In this case, the evaluation could center on the number of people who have gotten help, the economic and environmental contribution of the proposed solution, the sustainability of the project, etc. In like situations, the question is, "How does this solution improve peoples' lives?" And with respect to context, the criterion mainly targets the context in which the solution was proposed, including an examination of the challenge, its relevance, the prevailing culture and the geographic location. Consequently, the context criterion focuses primarily on the standard of living, or even the lifestyle, of people affected by the challenge and the context in which these people live.

The Hasso Platner Institute suggests three evaluation criteria: technical feasibility, economic viability, and human value. Technical feasibility means that the goal has to be technically achievable. Implementation of the idea must be possible through the use of existing technologies, materials or realities. In cases of economic viability, the idea must become a source of revenue for users or the company. And ultimately, from a human perspective, the idea must meet user needs.

# Chapter 3
# Design thinking in practice

This section will feature successful design thinking projects relating to the environment that team members for this guide put together with young and adult learners, as well as with members of the community. During these experiments, the success factors recommended by the international expert organizations interviewed were all taken into account, to the extent that it was possible to do so.

## 3.1 Two projects with young students

**Boutaina El Jai, Sylvain LeBrun**

### Project 1: Eco-friendly soaps

Design thinking was used with Grade 6 students from *École Le Sommet* in Moncton, Canada, in a project they undertook to make an environmentally low impact natural soap. Realizing that commercial soap contains products that are harmful to the environment and health, students wanted to produce an eco-responsible soap that smelled good and was chemical free.

***3.1 Source : Sylvain LeBrun, 2019***

During the *Observation-inspiration* phase, students conducted research using digital tablets to deepen their knowledge of soap making methods, the tools they needed to make the soap, possible ingredients, and so on. They also sought the opinion of people they know (parents, neighbors, etc.) to gain insight into their needs and what they liked and wanted in soap. During the *Synthesis* phase, students discussed the information they had collected in order to better define the issue. During the *Ideation* phase, wanting to come up with more ideas, the facilitator used the *Popplet* digital tool, which allows for the creation of concept networks. Using *Popplet* bubbles, students listed different fragrances, shapes, and textures that could be used in soap making. They then voted to choose three recipes that were all easy to make, mostly containing natural ingredients that would meet the needs of the users they had identified. The recipes they used were based on lavender and eucalyptus; aloe vera, honey and coconut; and olive oil and shea butter. At the *Prototyping* stage, three teams were put together and each of them made a type of soap. Hoping to increase interest in their soaps, students thought it would be interesting to produce soaps of different shapes and colors. Once the soaps were made, the students brought the three prototypes home to get feedback from their friends and family and to learn of their preferences. During the *Test* phase, students were asked to use the *RealtimeBoard* digital tool to tally the votes and comments they received and to determine user preferences (lavender and eucalyptus). Coming back to the *Prototyping* stage, students made lavender and eucalyptus soaps that they made available to students and teachers in school washrooms. Finally, at the *Communication* stage, students prepared posters or presentations to demonstrate the benefits of their eco-friendly soap to other students, parents, and staff at their school.

Students made nearly a hundred eco-friendly bars of soap that they distributed to their friends, family and made available in school washrooms. They conducted an informal survey among users to get their comments and impressions about the soap recipe they favoured the most. Finally, they made sure that a good number of students, staff members and parents were made aware of the harmful effects of certain soaps on the environment. From one teacher's point of view on design thinking: "*Prototyping is a very interesting step in design thinking. It allows students to check out different ways of solving a problem. The ‘‘trial-and-error’’ method helps some students better understand a concept, its components, and its variables*."

**Project 2: Bat Shelters**

In recent decades, bat populations have decreased significantly due to white-nose syndrome. Grade 6 students at *Carrefour de l'Acadie School* in Dieppe, Canada, decided to take concrete steps to address this problem. Their goal was to build alternative shelters for bats to protect them from potential predators or harsh winter conditions.

***3.2 Source : Sylvain Lebrun, 2019***

During the *Observation-inspiration* phase, students conducted online research on what bats need to survive (their habitat, diet, predators, etc.). During the *Synthesis* stage, the class engaged in a discussion on the results of their research in order to better frame the problem. At the *Ideation* stage, seven four-member teams were put together. The digital *Popplet* tool was used to build a concept network where students could present the different ideas for bat shelters that they found on the Internet. Students were asked to come up with adjectives that would best describe a bat shelter and the criteria that bats prioritize in their search for shelter. While using keywords and descriptive adjectives (the language component of the project) during the *Ideation* phase of the exercise, the students came up with several words, for example: spacious, narrow, camouflage, etc. They then conducted further research on bat shelters that used the adjectives they had identified. Seven shelter models were selected for study, three of which were chosen for *Prototyping*.

The prototypes that were ultimately chosen were sent to the Atlantic Wildlife Institute, an organization that deals with the rehabilitation of wildlife in southeastern New Brunswick. The students received constructive feedback from experts on the prototyped shelter structure. For instance, it was recommended not to install branches or leaves on the shelter since branches could serve as a perch for predators, such as owls or hawks. Finally, the *RealtimeBoard* digital tool was used to highlight the prototypes and expert feedback, to compare the three prototypes and to enable an informed decision on the final prototype. The students ended up installing the bat shelters in the schoolyard, ensuring that the standards set out by the Atlantic Wildlife Institute were meticulously followed and by adding useful elements of the two other competing prototypes to the one that was ultimately chosen. One of the positive elements added was a grill at the entrance to the shelter (to give easier access to the bats) and an internal compartment (because bats prefer narrow spaces).

Students made sure that there was a nearby water source and that the bat shelters were pointed to the south or southeast, in order to maximize exposure to sun. Finally, at the *Communication* phase, students shared their environmental project by making oral presentations using posters and information from the school website.

According to the class teacher who took part in the exercise, "*The use of information and communication technologies (ICT) such as Popplet and RealtimeBoar during Ideation and Prototyping allowed students to witness for themselves the different approaches to building bat shelters and that information proved to be useful during the construction of shelters* ".

## 3.2 A project with education graduates in Ottawa

**Liliane Dionne, Louis Natacha, Maroua Mahjoub**

Between April and July 2018, students graduating from the Bachelor of Education program at the University of Ottawa took part in a design thinking experiment. The primary goal of the experiment was to gain a better understanding of what adults experience during the various stages of design thinking. The challenge for participating students was to improve upon the well being of international students through the planning and development of the University of Ottawa campus. The idea here was to focus on the implementation of design thinking, and on the different solutions suggested by participating students.

At the first meeting, which focused on the *Observation-inspiration* phase, participants were asked to define the needs of international students in relation to the outside campus environment. They were asked to target specific users whose needs might be in line with the goal of the project. Participants made it clear that the targeted users would be international students who lived year-round on the University of Ottawa campus.

Initially, participants mentioned that international students would likely want to search out their cultural communities, better integrate into the Canadian population, and take advantage of the green and natural places on campus for resting and relaxing. At the second meeting, participants continued the *Observation-inspiration* phase, where participants prepared questions for the ethnographic survey they designed to gauge the needs of targeted users. Each of the students taking part in the exercise interviewed two or three international students living on campus in one of the university residences. At a subsequent meeting, students were taught how to use the *RealTimeBoard* digital tool. Participants were asked to use this tool, at home, using an instructional page developed by the research team. This page displayed concept networks to be completed in order to illustrate the individual needs of participating users (see Figure 2). Participants completed this work at home. Since the digital tool was new, they needed time to master it well.

Here is an example of the page that was placed on *RealTimeBoard*:

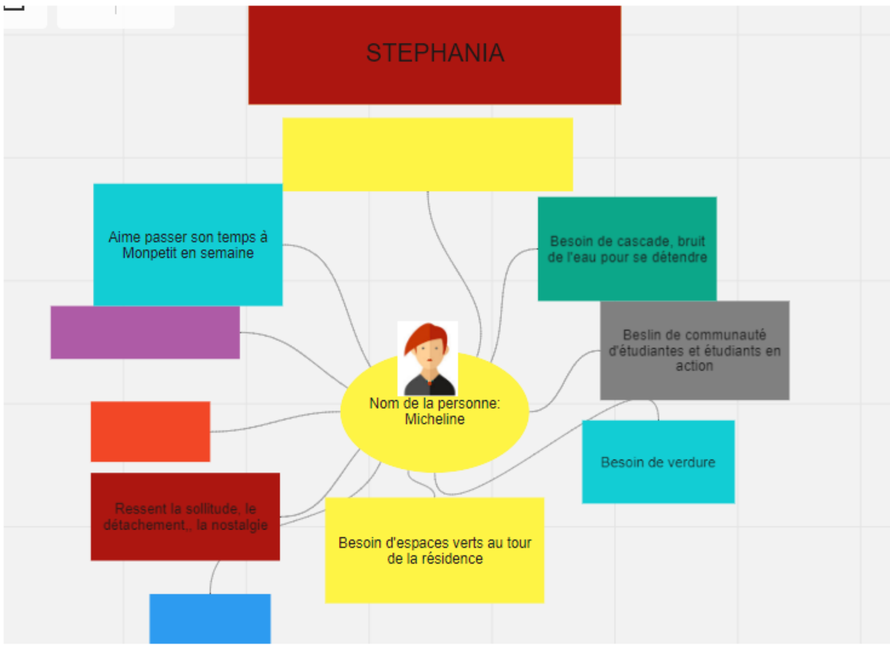


**Figure 2. Example of page from *RealTimeBoard* used to record the individual needs of users surveyed by participants**

At the third meeting, work continued on the *Observation-inspiration* stage, at the same time that participants undertook the *Synthesis* phase. At this meeting, the user needs that were compiled during interviews were grouped together on an empathy map, summarizing what users felt, said, saw and did within the campus environment. After completion of the interviews, participating students came up with further user observations in relation to the campus, including: lack of vegetation (particularly native vegetation), the need for shaded workspaces, works of art, spaces to socialize and work in teams, places to meet people from the community, a mosque, entertainment venues, places to eat and sit outside, campus directories, and places reflecting elements of their own culture (flags of their countries, for example).

At the fourth meeting, the discussion centred on the *Synthesis* and *Ideation* steps. The conceptual challenge was drafted several times and was then critiqued using the *RealTimeBoard* tool. The latest version of the conceptual challenge, with which everyone agreed, read as follows: *How could outdoor physical spaces be developed on campus to promote the well-being and learning conditions for international students living on campus?* Solutions were then posted on sticky notes and arranged into categories. Following the presentation of ideas, the *RealTimeBoard* was used in class to tally the votes in favour of the solutions. Icons were used for voting purposes. The participants finally chose the following solutions: the installation or addition of pergolas, board games and native plants, the provision of space for intercultural meeting places, the addition of benches, public directories, water fountains, art work, electrical outlets, tent trailers (for relaxation or study) and an area dedicated to featuring the variety of nations represented on campus (with flags from the countries of international students). Between the fourth and fifth meetings the *Ideation* stage remained active. New solutions were proposed and ideas that had been suggested earlier were evaluated and amended. *RealTimeBoard* was used to display and evaluate new solutions.

At the fifth meeting, the *Ideation* stage continued to be implemented whilst the *Prototyping* and *Testing* stages began. Votes cast online to assess written solutions were tabulated using *RealTimeBoard* and participants used that tool to explain the solutions they proposed. The goal here was to select the best solutions for *Prototyping*. With the use of DIY equipment, each of the two teams then proceeded to create a prototype to address conceptual challenge (see Figure 3).

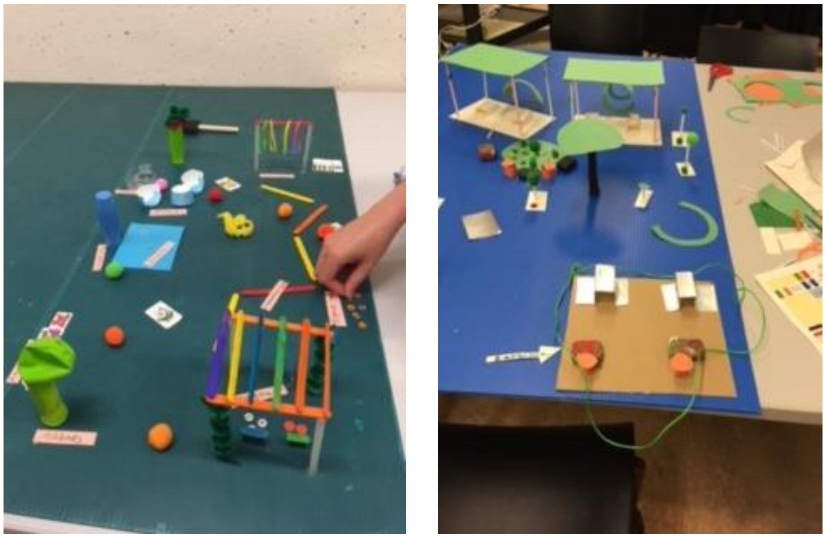

**Figure 3. The prototypes developed by both teams**

The prototypes were photographed and the images entered into *RealTimeBoard*. Students suggested other solutions for implementation on campus, including: pergolas, ponds, aquariums, plant walls, gardens with adjoining ponds, paintings, green roofs, hives, benches, swings, water fountains, organic clay pots, outdoor amphitheatres, giant amusement games, native parks and solar panels. A clearer distinction was also suggested between what can be considered relaxation spots, study areas and meeting places. Some of these elements were added to the mockups. Between meetings 5 and 6, the participants checked with users to find out how they felt about the two prototypes that had been developed. Photographs of the prototypes were entered into *Tinkercad*, another digital tool, to facilitate consultations among users easier. Users' opinions were then entered into *RealTimeBoard*.

At the sixth and final meeting, the *Testing* stage began. Participants shared users' opinions and possible improvements to the prototypes were considered and discussed. The best ideas from both mockups were combined, resulting in the production of a new one, which took into account the latest user opinions (see Figure 4).

**Figure 4. Final prototype of a wellness zone on campus, corresponding to the needs of international students**

As a final solution towards improving wellness among international students, the participants proposed the *Megwetch* Park ("Megwetch" means "thank you" in Anishinaabe), a spot on the campus that would include the following design elements: pergolas, trees, flowers, water fountains, swings, ping-pong tables, a giant chess board, benches made out of tree trunks, sheltered study tables, an outdoor classroom, shaded meeting areas, trails, artwork and a garden for flying international flags.

## 3.3 A project with education students in Quebec City

**Vincent Richard, Boutaina El Jai**

**Background to the test**

In the fall of 2018, design thinking became part of basic training for future primary school teachers at Université Laval, in Quebec City, Canada. The initial objective of the project was to introduce future teachers to a significant technological design approach that would influence their training: the plan was to have students experiment with the design process in order to have them implement it in primary science classes. The approach was therefore adapted to meet the program's academic framework, namely a course that would span a 15-week period, with weekly meetings, instructions, and guidelines available on the course website, regular classroom support using activities and independent teamwork. It became a long, drawn out undertaking, completed using 4-person teams, who contributed to the summative evaluation of the course.

**Environmental issues addressed**

In this particular case, students lent their attention to a current environmental issue: the issue of drinking water in Quebec City. This issue was chosen for several reasons: a) it had been a news item for more than 5 years and was still relevant when the activity was undertaken (news item means reporting that made the headlines of local media on a regular basis), b) it was an issue that directly affected the local population, involving several stakeholders and opposing viewpoints and, c) it was a complex problem, for which there was not, at least at the time, any single and simple solution. For example, local newspapers regularly reported on the problems related to the protection and pollution of sources for the city’s drinking water, problems relating to overconsumption, waste, poor water consumption trends, and problems concerning how drinking water was ultimately brought to the consumer (obsolete equipment, maintenance issues, upgrading).

Another variable had to be taken into account in the assessment of the issue: the overabundance of water resources in and around Quebec City (St. Lawrence River, numerous rivers and lakes, and readily accessible water tables) which, from the very beginning made it difficult for the general population, and for the students in particular, to understand.

**The approach adopted in class**

In class, the students used a six-step process:

1. *Observation-inspiration*: students were invited to take stock of their knowledge in relation to the problem at hand and to conduct a literature review exposing the various points of view of experts who examined the issue;

2. *Synthesis*: At this stage, students were asked to single out a relevant sub-problem that affected real users and that could realistically be resolved during the course;

3. *Ideation*: this third step marked the beginning of the planning stage, allowing for the identification of a solution that really addressed user needs;

4. *Prototyping*: this step consisted of building a "concrete" object: the prototype;

5. *Testing*: Steps 4 and 5 were considered iteratively. Since *Prototyping* involves trial-and-error, users must validate it and efforts must be made to improve upon the different versions of the prototype;

6. *Communication*: The last stage, considered to be an integral part of design thinking, enabled students to report on their approach through the production of a short video designed to inform the entire population about the merits of the solution and the quality of the end result.

Nearly two-thirds of course time was spent on the first three stages, since a thorough grasp of the matter gave students a better understanding of the issues and constraints relating to the problem chosen by each team.

Throughout the session, students were required to use a digital kind of "discussion forum" tool such as *Knowledge Forum 6.0 (KF),* to allow for sharing their points of view, ideas and research.

The choice of this digital tool was prompted by its ease of use, the availability of numerous writing aids (scaffolding, keywords, feedback) as well as the visual appeal relating to the co-development of ideas (a "conceptual map" type of structure). Since it is also an evaluation tool, very specific instructions on the use of *KF* software were provided (minimum number of contributions at each stage, the minimum number of words, mandatory reading of team members' contributions, etc.).

**Some solutions put forth by future teachers**

The teams singled out two main types of problems relating to drinking water. The first was described generally in terms of the citizenry’s bad habits relating to water consumption, owing largely to lack of information. As well, the teams identified more "technical" problems related to the waste or mismanagement of drinking water (including poor management of water sources, the water distribution system and drinking water consumption).

Several of the solutions put forth involved user awareness. For instance, one team raised the idea of producing a guide for teachers that could serve to educate children on the responsible use of drinking water resources. Similarly, another team suggested the development of an educational program that could be implemented in Quebec City parks (targeting citizens) to raise awareness about the population's water consumption habits. Yet another team developed a teaching "kit" for the use of "Beach squads", meant to sensitize boaters on the vulnerability of water resources (lakes, rivers). Some "political" solutions were also proposed: some teams stressed that regulation is part of the problem and should be adapted to protect sources of drinking water and to regulate its use. Several solutions also bore on "technical" issues. Solutions put forth to address this kind of issue were discarded, just like many others "that exist and have been adapted to address the problems in Quebec City". Road de-icing salts were identified as a major problem and some teams contemplated the development of white and green roads around a particularly important source of drinking water in Quebec City: Lac-Saint-Charles. Other teams suggested setting up temporary wastewater treatment sites directly at the source. This involved dealing with huge snow storage sites that spring up in the parking lots of certain shopping centers. In a nutshell, although students often did not feel technically qualified to develop an "engineering" solution for the various problems related to the issue of drinking water in Quebec City, they generally took the time to adopt existing solutions and to adapt them to the situation as they saw it.

## 3.4 A project with engineering students in Moncton

**Anne-Marie Laroche, Michel Léger, Sylvain LeBrun**

### Context of the project

The training of engineers in Canada requires a solid foundation in design. Moreover, Engineers Canada expects the curriculum cover to "a significant engineering design experience under the professional responsibility of professors licensed to practice engineering in Canada. This large-scale design experience is based on previous knowledge and skills and ideally it also allows students to become familiar with the concepts of teamwork and project management. Usually, students must meet this requirement when planning to graduate from an engineering university.

In order to prepare students for this training activity, several courses require the completion of a design project. However, students design projects according to a so-called *conventional design* method that mainly takes into account client needs. In the case at hand, the idea was to change the approach and have students use design thinking to craft solutions in a course on water treatment.

**The issue surrounding the quality of drinking water**

Students were tasked with finding a solution to ensure that residents in Cap-de-Cocagne (New Brunswick) could consume water with arsenic concentrations that met the standards of Health Canada. In New Brunswick, groundwater may contain arsenic (As). This element is naturally present in the bedrock. In some areas of the province, groundwater levels of arsenic can exceed the minimum acceptable concentration of 0.010 mg/L. The only way to detect arsenic in water is through chemical analysis. There is no other way to detect its presence since arsenic is tasteless, odorless and colorless.

Health Canada considers that arsenic can have adverse health effects. Exposure to arsenic over a few days to a few weeks can cause nausea, diarrhea and muscle aches. Exposure over several years, or even decades, even at low concentrations, can cause cancer.

Students were tasked with finding a solution that would ensure safe water for the population of Cap-de-Cocagne, thus enabling people to access water that met the standards on arsenic concentrations. To conduct their work, they had to consider the population's trends regarding water, available public funding, and development forecasts.

**Design steps**

Students had to use design thinking in carrying out the project. In fact, some civil engineering groups have already incorporated this process into their practice. Further, the *American Society of Civil Engineers* has prepared a training module on design thinking (**https://news.asce.org/how-to-cultivate-innovation-in-civil-engineering/**).

The design thinking approach in this case was carried out using pre-determined steps:

1. **Displaying empathy** (*Observation-inspiration*): Students had to gain an understanding of the people for whom they were creating a design, that is to develop empathy for users and what mattered to them.

2. **The definition** (*Synthesis*): This step involved classifying and synthesizing the results obtained in the first step into captivating needs and flashes of genius. This step involved "development" rather than "research". The two objectives here were to gain a deeper understanding of users and the design space, in order to draft a problem statement that could provide concrete results. The students' point of view had to embody the ideas and needs of specific users as set out in the previous step.

3. Coming up with a **design** (*Ideation*): the goal in this instance was to ponder an array of solutions, all of which presented numerous, varied and diverse ideas. The use of these solutions would make it possible to build prototypes to test with users.

4. **Creating a prototype** (*Prototyping-testing*): the objective at this stage was to build prototypes incorporating ideas that had been brought forth and to share these ideas with others in assessing the prototypes in terms of form and function. The evaluation of these prototypes was undertaken using the opinions of experts, novices, and users.

5. **The communication stage** (*Communication*): The goal here was report on the results of the project for the benefit of all involved.

**Recommendations from future engineers**

After meeting with people concerned by this very current issue, it was finally possible to get a clear picture of what the issue really meant. The conceptual challenge was to come up with a solution on how to treat the arsenic contaminated well water of Cap-de-Cocagne residents. The students decided that the first order of business was to determine whether the arsenic levels in wells was above the acceptable limit. Students were aware that the arsenic concentration varied quite a bit from one well to another. Since the problem was not at a critical point for everyone involved, it was important to not only determine how to fix the problem, but to determine as well whether each citizen had significant levels of the element in their well water. Well owners were encouraged to have a sample of their water tested to determine whether further action was warranted such as coming up with a technical solution. The solutions that were then chosen all proved to be feasible and their use depended mainly on the means and priorities of the homeowner. The students suggested the following technical solutions:

- a reverse osmosis treatment system;
- a distillation system;
- the distribution of water bottles;

- an anion exchange system;
- an iron oxide absorption system.

What emerges from the students’ work is that they were able to take on the task giving full consideration to the needs of the local population. Usually the solutions put forth in situations like this are almost entirely technical in nature without necessarily taking into account the concerns of the people directly affected. Further, the recommendations put forth target multiple solutions that can potentially address the needs of the greatest number of people. The recommendations the students put together in this case could not all be applied to the entire population of Cap-de-Cocagne. In fact, depending on the user's situation, one of the systems should be used if the arsenic levels were critical.

In reaching these recommendations, students were inspired by the comments gathered during phase one (*Observation-inspiration*). It is worth noting that this project forced students to venture outside their "comfort zone" as designers. The undertaking shook them up by requiring that they put themselves in the shoes of residents of Cap-de-Cocagne, and the project required a sustained effort on their part throughout.

## 3.5 A project in Morocco with women from the community

**Diane Pruneau, Abdellatif Khattabi, Boutaina El Jai, Maroua Mahjoub**

In the Ourika region of Morocco, floods brought on because of climate change are damaging drinking water systems. Those victimized by this problem, mainly women, needed help in their search for solutions. Design thinking and Facebook were chosen to help ten Moroccan women with little education to find a solution to the problem of unsanitary drinking water, caused by the floods. Through the use of design thinking and Facebook as support and networking tools, ten women from the Ourika region, near Marrakech, got help on how to adapt to the frequent flooding of the Ourika River. These women, chosen for their minimal literacy skills, came from six isolated douars located about 35 km from Marrakech. The economy in this region is mainly based on agriculture and livestock. Mining and industrial activities, tourism and handicrafts also play important roles. Since 2011, owing to the effects of climate change, there has been an increase in floods and their frequency in the Ourika wadi. The floods had taken a devastating toll on the landscape, agriculture, human capital, infrastructure, and food security. Women who headed their families while their husbands were away working in Marrakech were forced to deal with the floods and to protect their families and property.

Work with these women spanned a three-year period, from March 2015 to February 2018. During that period, the Ourika experienced three small floods. Design thinking served to guide the activities undertaken by the women in the 15 workshops in which they collaborated. A private Facebook group (*Femmes* GIREPSE) was used regularly as a networking tool to reach women who lived in remote areas. In the initial stages of design thinking (*Observation-inspiration*), the women were interviewed individually and they were asked to describe the flooding and their needs in light of this disaster. A *Journey Map* that two researchers prepared for the women, that is to say a visual representation summarizing their experience before, during and after a flood, allowed for the drafting of the first *Synthesis* of the flooding problem.

In August 2015, during the first two two-day workshops involving all the women, the *Observation-inspiration* and *Synthesis* steps were once again applied. The women were invited to note their comments on the previously prepared *Journey Map* as a means of explaining their experience during flooding. They were also trained on how to use computer tablets, the Internet and *Facebook*. The women then chose to work on a more circumscribed and easier to solve issue: the quality of their drinking water following the floods. *Facebook* exchanges started in September of 2015, with the women communicating among themselves and with the research regarding flooding and the sub-problem of water quality. The women were asked from the outset to post photos, videos, and comments on local floods on *Facebook*. *Facebook* was then used to ask the women specific questions on a weekly basis and they were asked as well to explain the sub-problem of water quality after the flooding: *Where? When? Why? Impacts? Solutions?* etc. The women were asked to answer questions on their observations, regardless of their location, using *Facebook* tools: comments, videos, photos, emoticons, etc. Workshop 3, held in November of 2015, had the women gather for a one-day meeting in order to complete the *Synthesis, Ideation, Prototyping*, and *Trials* stages of design thinking as they relate to the water quality sub-problem. During the workshop, the first order of business was to put together a summary of the various components of the drinking water problem and the solutions that had been considered. The water that villagers collected from the wadi was then tested with the women to check its quality: ph, coliforms, bacteria, etc.

***3.3 When participants invent filters to purify water (Morocco).***

The women were then asked to invent filter prototypes using domestic materials: cloth, coal, plastic bottles, sand, rocks, etc. They had to check how efficient the filters were in cleaning the water. After completion of Workshop 3, *Facebook* exchanges resumed between November 2015 and January 2016, taking into consideration the *Prototyping*, *Trials*, and *Communication* steps. The women attempted to build filters at home and shared their attempts on *Facebook*, where their peers posted comments. On *Facebook* a general assessment of ideas completed the *Phototyping* stage.

Thereafter, feedback (*Observation-inspiration*) was provided during a workshop in March 2016. The challenge was presented as follows: *How can we prevent the contamination of the water from the "wadi"*? *Ideation* was used once again and participants came up with the following solutions: seeking better water sources, treating well water using the right amount of chlorine, educating neighbors to avoid throwing trash in the river, building strong waterways, keeping wells away from flood plains, keeping water cleaner, and reducing waste by composting leftover food. Though the women tried to use the solution of "educating neighbours to avoid throwing trash in the river", the idea did not garner much success. A follow-up analysis was conducted on *Facebook* where the women posted photos of their household waste for other group members to see. In the photos of waste posted online there was a significant amount of food waste and plastic bottles. The project team decided to provide the women with composters and to show them how to make compost (in September 2016). Once the composting process got underway, the women made inquiries through *Facebook* to find out how to tell when composting was completed. Meantime, the research team and two women who had gotten comfortable using the Internet posted photos of how to recycle plastic bottles. Various potential repurposing ideas were explored: reuse of bottles for gardening, decorating, creating art, jewellery, etc. To share ideas on the practical application of these solutions the women conducted a workshop (in April 2017) where they made prototypes of jewellery, candy boxes, and coasters from plastic bottles. Jewellery turned out to be their favorite prototype.

After the workshop, the women reacted favourably to the researchers' suggestion of starting a women's cooperative specializing in waste recovery and turning waste into jewellery and compost. At another workshop (August 2017), they tested their prototype jewellery in consultation with people in a community in the Ourika region. In October 2017, the cooperative's first exhibition and sale of jewellery was put on in Rabat and five women took part in the activity. The *Facebook* group planned the event by providing tips on how to welcome visitors to the exhibition and how to exhibit the jewellery.

During the exhibition, customers commented on the jewellery prototypes and the women posted photos of which prototypes sold the most. Throughout October, the Marrakech-Safi Regional Environment Directorate provided the women with fast acting composters and installed them in their houses to ramp up the cooperative's production. In November 2017, the women took charge of their cooperative and signed up by themselves to take part in a local fair in Marrakech. They posted photos of their jewellery display on *Facebook*.

## 3.6 Affordances and accessing collaborative digital tools (ICT) in design thinking

**Viktor Freiman, Vincent Richard, Jacques Kamba, Takam Djambong, Caitlin Furlong**

Some researchers feel that there are several advantages to using digital technologies in solving environmental problems:

- Promoting the sharing and dissemination of information;
- Fostering the collaborative and effective resolution of issues that affect the entire community (Barborska-Narozny, Stirling and Stevenson, 2016, Beche, 2012);
- Fostering the coordination of actions, the popularization of projects and the strengthening of citizen engagement (Beche, 2012)
- Developing critical thinking by having learners ask questions, review materials and discuss issues (Pinzón and Nova, 2018, Squires, 2014).

Two collaborative digital platforms were tested: *RealTimeBoard* (in Ottawa) and *Knowledge Forum* (in Quebec City), during the problem-solving activities undertaken by Ottawa and Quebec City students (see sections 3.2 and 3.3).

### 3.6.1 Testing the *RealTimeBoard* platform in design thinking

*RealTimeBoard* is an online whiteboard that allows users to collaborate, write, and even draw on the same screen while using different computers (Squires, 2014). This platform also allows users to see who is doing what. When someone makes a change to a table, the history function of the software allows users to determine who made the change.

As part of the Ottawa project, *RealTimeBoard* was used when students were asked to design the university campus to meet the needs of international students (see Section 3.2). This digital platform allowed participating students:

• to monitor the project’s progress (in seeking to better understand the issue under review, to gain overall and specific perspectives of the issue and the various steps needed to solve it);

• to steward the project’s progress in and outside the classroom (hybrid approach, ongoing contributions viewable for all participants);

• to learn what other colleagues do and say (gaining information); and

• to provide feedback on the work of other colleagues (to express themselves).

In implementing the various stages of design thinking, *RealTimeBoard* was used in several ways. During the *Observation-inspiration* stage, participants were encouraged to use concept networks to allow for recording the individual needs of the international students who took part in the interviews. At the *Synthesis* stage, students completed empathy cards summarizing the needs of the numerous users (see Figure 5). Similarly, during the *Synthesis* stage, various alternative conceptual challenges were posted on a *RealTimeBoard* page for discussion and comments (see Figure 6). This virtual space also served as a means of sharing and commenting on various solutions (see Figure 7) and of sharing *Prototyping* results (sharing models representing solutions) and presenting prototypes to users to get their feedback (see Figure 8).

The *RealTimeBoard's* affordances in this case were to *collaborate* online (co-construct an empathy map), *synthesize* user needs (identify several conceptual challenges, vote on a challenge), *propose* and *evaluate* ideas (add new ideas, evaluate and transform the ideas of others, vote on solutions), *disseminate* the two prototype solutions (download photos of both models), and have the solution *evaluated* (disclosing user opinions on prototypes).

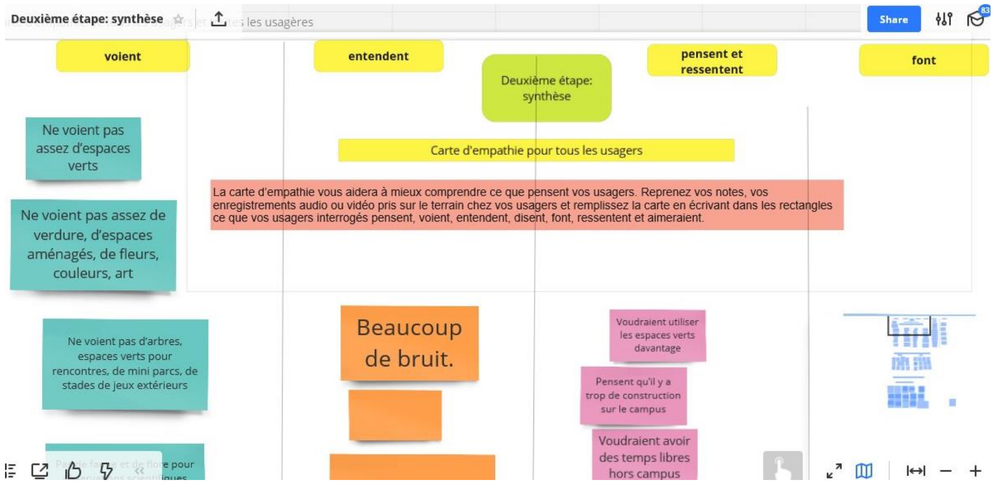


**Figure 5. Collective representation of user needs (Synthesis step)**


**Figure 6. Using emoticons to vote on the conceptual challenges (Synthesis step)**


**Figure 7. Table representing solutions and including text, photos and links**


**Figure 8. User Comments on Prototypes (Trial step)**

Solvers eventually got used to using *RealTimeBoard* by following these steps:

**• Slow entry of data:**

Positive expectations; lack of time to master the tool; shoring; need for support;

**• Exploration:**

Initial successes (concept networks and magnetic cards); initial difficulties (mastering the tool - zoom);

**• Increasing understanding:**

Practice; perseverance; help as needed; discovery of new benefits and features: functions and tools (use of emoticons for voting purposes);

**• Mastery:**

Sustained individual and collective effort; mutual help - sharing; improvement on effective uses;

**• Creativity:**

Increased ease of use; autonomy; reduction in need for assistance; desire to go further; ongoing discoveries (links, photos, messaging); convergence towards a common group goal (seeking solutions).

Using *RealtimeBoard* was a truly new platform for all participants. However, not everyone used the tool in the same way. Initially, dealing with technical tasks (how to do something with the tool) seemed to take up more time.

Gradually, the collective learning process seemed to converge towards the common goal of finding a solution to the problem. Time spent on task, support and peer help all appeared to be important throughout the process. So, from a design thinking perspective, the dynamic and complex dialectical relationship between problem-solving tasks and accessing digital tools appeared to help learners forge ahead: the more they followed the steps, the greater they appeared to rely on the use of digital tools in coming up with a solution, which could have a beneficial effect on the quality of co-created lessons and solutions.

The following three phases of appropriation were singled out in design thinking:

• **Entry - exploration**: few links to problem-solving; the tool's use is still abstract for many, so emphasis is placed more on accessing affordances.

• **Increase in understanding - mastery**: no more links to the problem; positive affordances are increasingly present; increase in the understanding of the issue and working together towards finding a common solution;

• **Aiming for creative and thoughtful use**: the common understanding of the tool's affordances lead to the emergence of a more complete understanding of the issues and possible solutions.

### 3.6.2 Testing the use of *Knowledge Forum* in design thinking

When integrating design thinking into the training of future primary school teachers at Laval University (see section 3.3), *Knowledge Forum* (*KF*) was used as a tool for the co-creation of students' knowledge. It is worth recalling here that the students in this case were involved in examining the poor quality of drinking water in Quebec City. By itself, *Knowledge Forum* presents discussion-centric features akin to those in a conventional discussion forum, presenting the various contributions of users in the form of "networks" that they can freely roll out (see Figure 9). Users could therefore make contributions that could be discussed and refined by the other members of the team.

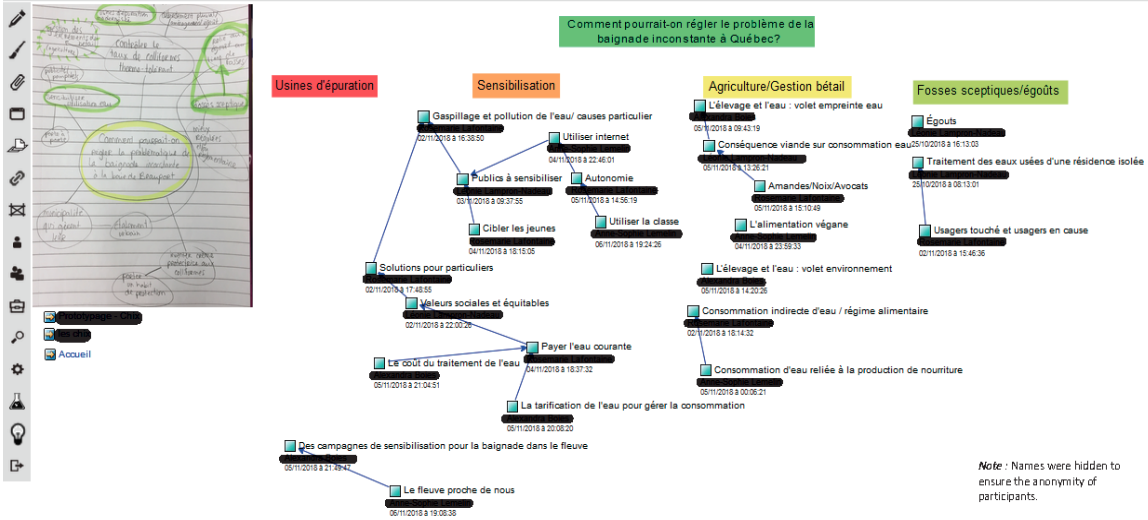


**Figure 9. Example of discussion on *Knowledge Forum***

## Spatial organization of contributions in the discussion area

The following analysis highlights some affordances from the preliminary data analysis. While it goes without saying that different teams need to organize their various member contributions, it is interesting to note that this organization took on different forms. Two ways of organizing contributions are: a "chalkboard" organization (see Figure 10) and a "tree" organization (see Figure 11).

**<u>Organization using tables</u>:** This way of organizing team member contributions sets those contributions out according to the stages of design thinking that have been completed. The various stages of design thinking are visible on the abscissa (*Inspiration-observation*, *Synthesis*, *Ideation*, etc.) and, on the y-axis, a listing of the different contributions.

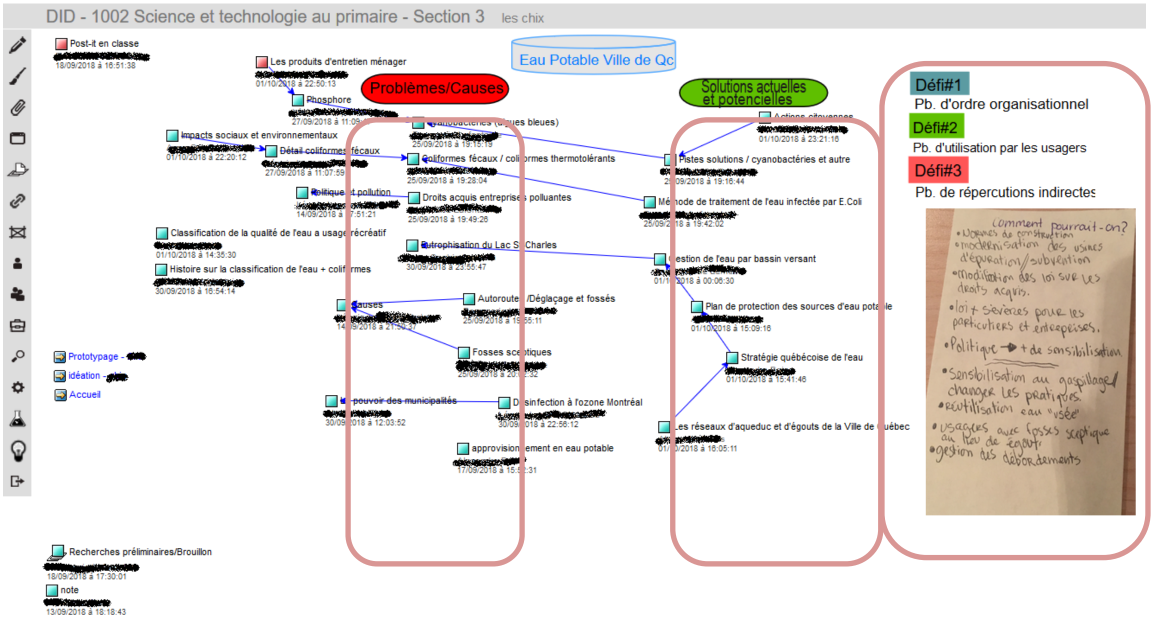


**Figure 10. Organization in columns of contributions**

In this case, the discussion is clearly reorganized to reflect the various stages of design thinking. Certain "peripheral" contributions that have little or no relation to the main discussion are also visible.

**<u>The "tree" organisation:</u>** This second way of organizing things comes from a long series of emerging contributions and it has its own "logic" which no longer relies solely on the logical steps of the exercise.

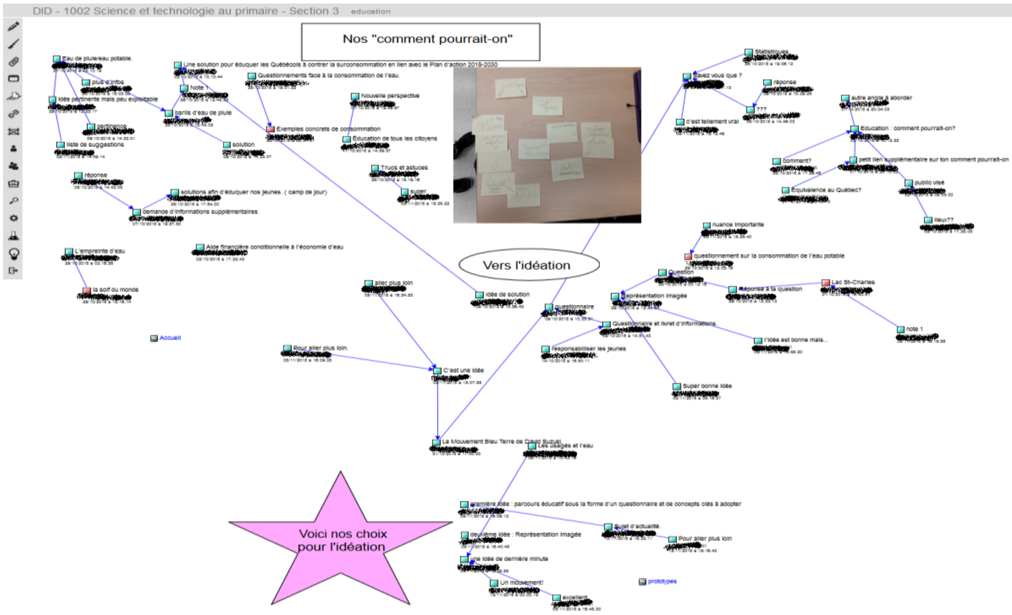


**Figure 11- Organization "tree"**

The structure of the discussion in this kind of organization is more complex than that in the tabular model. There are nonetheless benchmarks that can be used to identify the various stages of design thinking.

**"Short" and "long" threads**

Contributions may also result in feedback from other members of the team. Other more or less “long” versions of “threads” may also appear. Two kinds of discussion seem to ensue: they may be called "short" threads and "long" threads. Short discussions feature a number of contributions that is equal to the number of team members (in this case, four) or less. Note that several teams only use short discussions, rarely exceeding four contributions per thread. These are usually “linear” discussions, meaning that a response is given in to the initial contribution, and then another response is given to that response and so on, without opening further discussions on the responses that are given. "Long" threads are organized in another way: these threads are double to triple the number of team members (from 8 to 12), some with one or two "nodes" (one response resulting in multiple responses in the discussion thread). Long threads are rarely linear and are therefore more difficult to organize. Not surprisingly, there are more long threads in Step 3 than in Steps 1 and 2 of the process, which may indicate the adoption of *KF* as a discussion tool.

**Using “pivots” in the discussion**

Generally speaking, teams use what might be considered as "pivots" in discussions. Numerous discussion pages feature the addition of graphic elements (images, photos, titles), which serve either as "summaries" of available elements or as elements that have broadened the discussion. In both cases, from a visual perspective, these graphic elements serve as "support points" for discussions.

**Different kinds of contributors**

When considering who is making contributions, several characteristics stand out:

> 1) Some people initiate several discussion threads, whereas the others contribute by responding to their colleagues, rarely taking the initiative to start a discussion;
> 2) Some people work strictly within the limits set for completing work (in terms of how many contribution they make) while others, following the instructions provided, involve themselves more freely in the discussion and participate much more than they are asked to;
> 3) Some team members often contribute more than others. However, this does not necessarily mean that they demonstrate more leadership in the discussions (a high number of contributions does not necessarily correlate with a higher number of responses). In the end, it seems that in general all team members generate an equivalent number of contributions receiving one or more responses.

In summary then, preliminary analysis indicates that for participants the affordances identified through the use of *KF* in design thinking, revolve around how the team discussion is set up. The analysis in this case suggests that participants developed a logical approach specific to the exploration and resolution of problems. The link between contributions and the various stages of design thinking is clearly established in the way *KF* is set up. In addition, the subsequent analysis suggests that *KF* allowed participants to structure their contributions. In other words, teams were concerned with “advancing” the discussion, organizing it in such a way that in addition to establishing a linkage with the stages of design thinking, the discussion produced concrete results.

Finally, the analysis suggests that teams used pivots (images, contributions, reference texts) as a "guide" to help them define the contribution of each member.

### Student appropriation of *KF*

As for student appropriation of *KF*, the distinction needs to be drawn between the appropriation process and the degree of appropriation.

### Appropriation process

The preliminary analysis of the situation suggests a two-step process in the appropriation of digital tools: firstly, attention focused on basic functionalities without regard for the assigned task, and secondly, consideration was given to choosing the appropriate software depending on the task at hand.

As for the digital tool itself, students pointed out that is was not user friendly, was not very attractive and that its functionality was not intuitive. Students also mentioned the "passive" nature of the tool in that it didn't "suggest" any steps. Generally speaking, this step took two to three weeks of courses. These findings appear to be generalized. Moreover, students did not hesitate to suggest "possible improvements" to the tool either in terms of aesthetics or making it more user friendly. It is fair to say that students found this first step rather demanding and that they did not like it very much.

In a second step, once the basic functions of *KF* were mastered, it became apparent that users were prepared to reconsider using the tool when following the steps of design thinking. This second phase of the appropriation process was marked by the recognition of *KF's* "power" (in the words of one team). All of the teams came more or less to this conclusion. This observation was rather generalized among all teams: the students generally felt comfortable using *KF* as they saw fit once the basic functions were mastered.

It was considered important to highlight these two experiences that clearly had a bearing on the dynamics of the whole process. A radical change appeared to surface when using *KF:* although during the first stage, students' questions involved a little "irritation" on how difficult it was to use the tool, ("How do we do this or that?"), students did not generally exhibit the same irritation in the second stage; rather, they were more enthusiastic ("Is it OK if we use titles to classify our contributions?")

**Levels of appropriation**

Since all teams had to actually go through two stages of appropriation, it seemed possible to distinguish between the two stages they all experienced: a functional level of appropriation and a creative level of appropriation. As its name suggests, "functional" appropriation refers to the teams' appropriation of the *KF*, enabling all team members to follow the instructions over the duration of the lengthy process. The project evaluation indicates that the overwhelming majority of students responded favourably to work demands and demonstrated an appropriate use of the *KF* to discuss issues with their team members and to explore possible solutions. This level of appropriation is considered to be "adequate", but it still remains a relatively simple appropriation level to achieve.

As for "creative" appropriation, students demonstrated an ability to use the advanced functions of the discussion platform (scaffolding, "rise above" notes, comments, embedded videos) to enhance the discussion and especially, to present prototypes/tests. The use of these tools began without students asking to do so, (save, perhaps for scaffolding, which was brought up at the beginning of the session). This level of appropriation indicates a greater mastery and understanding of the steps in design thinking as well as a more beneficial use of the tool for sharing and discussion.

# Chapter 4

# The advantages of design thinking and its use in science education, and education for sustainable development (ESD)

**Diane Pruneau**

## Advantages of design thinking

The survey of twenty international organizations, all experts in design thinking, demonstrates the added value of design thinking in solving complex problems. It also allows for a better understanding of the success mechanisms involved in the approach: empathy towards users, iteration, specific teaching strategies that are effective at various stages, appropriate definition of the conceptual challenge, concrete prototyping, enhanced environment conducive to collaboration, reflective use of collaborative technological tools (ICT), etc.

The testing of design thinking among elementary students, university students, and people in general shows that the approach holds great promise for working with people who themselves analyse local issues, propose solutions and test them. Results from the first analysis of the approach reveal that because of the emphasis it places on empathy (user needs), design thinking seems to "humanize environmental problems", which then become tangible and well understood, taking into account their harmfulness. Getting the problem solvers to improve the situations under review increases as the problem space expands and the teams actively collaborate to propose and improve upon solutions. The problem space expands to include not only the scientific aspects of the matter but also the social aspects associated with the issue. The problem space is flush in terms of users' emotions, consequences and human risks, all of which automatically shape the suggested solutions. The solvers really want to find effective solutions to help specific people, whom they have come to better understand by virtue of their involvement.

Environmental problems are no longer "emotionally neutral" or foreign to problem solvers; they are also coloured by the feelings of real people (users). Thus, the problem space constructed during design thinking seems vast, systemic and analytical enough to properly present complex problems.

A broad and well-organized problem-space is conducive to the proposal of solutions considered for the situations under review. Finally, the human aspect of the problems and the challenge of team collaboration to solve problems that "bother" people seem to interest the problem solvers.

Are the solutions deriving from design thinking original? According to the organizations surveyed and according to the test results of six groups, it appears that solutions emerging from design thinking are numerous and varied, but not necessarily always original. The creativity and technical knowledge of participants, the input from facilitators (who more or less encourage innovative thinking) and the strategies used during the *Ideation* and *Prototyping* stages could all influence the degree of innovation present in the solutions. However, the proposed solutions, without being completely new in environmental matters, seemed unpredictable at the start of projects and also very different from the initial solutions that had been spontaneously brought up. For example, in the case study involving the Moroccan women (see section 3.5), who could have imagined that the participants, all flood victims, would end up creating jewellery and making compost to reduce waste in their region? The assessment of this approach showed that the solutions proposed by the problem solvers very often meet user needs and that they are not identical to the initial solutions that had been quickly proposed at the beginning of the course. In-depth knowledge of the situations and user needs apparently leads to the design and adoption of appropriate solutions, which were not obvious from the start. The appearance of these new solutions midstream could be sheer creativity.

It was impossible during testing to determine whether the solutions were truly effective because the participants hardly had time to complete the *Communication* stage of their work. This study should be continued in order to systematically evaluate the factors that influence the originality and effectiveness of solutions deriving from design thinking. To do this will require the observation of solutions implemented in the field and the systematic use of criteria to assess creativity.

**The benefits of ICT in design thinking**

Should collaborative digital tools be used when implementing design thinking? In their experience working with groups, the 20 organizations we interviewed used some digital tools. Their argument relating to the limits of ICT use is based on the low level of familiarity among the problem solvers using various digital tools, which highlights the need for discussions on digital literacy (see, in this respect, the work of CompeTI.CA (ICT Skills in Atlantic)). On the other hand, tests conducted among adults using design thinking and collaborative digital platforms and social media (*RealTimeBoard*, *Knowledge Forum* and *Facebook*) highlight several beneficial affordances. Depending on the activities undertaken, the three ICTs used by the team in this study demonstrate their usefulness as tools for the following:

- serving as the visual, synthetic and organized representation of complex problems (in textual, graphic and schematic formats, using various online functionalities which serve as conceptual and collaborative illustrations and points of support);

- aiding in the collection, analysis, processing and dynamic and efficient sharing of available information (structuring, restructuring, development, critical analysis, online backup and dissemination of collaboration between team members at different stages of problem solving throughout the project);

- ensuring the effective management of the resolution process (consensual identification of the harmful parts of a problem and the conceptual challenge it presents);

- serving as a source of inspiration, reflection, support, and motivation to continue working remotely (in between face-to-face meetings);

- constituting a source of creative support, since the various parts of the problem and the numerous solutions appear side by side on the screen and can, therefore, be moved more easily into the virtual space and then be modified or combined to reveal new ideas (innovation is often a question of establishing connections);

- serving as the means for communication: the team gradually builds interpersonal relationships, which facilitates the ability to express themselves and work together (important for unfettered creativity!).

As it evolves, design thinking will have to take into account the extra time and techno-pedagogical support required for problem solvers to access new digital tools and to better use their relevant affordances in problem solving.

**Use of design thinking in teaching science and technology**

Understanding the success factors of design thinking could make it easier to implement this kind of investigative approach in many Canadian science and technology programs. Design thinking could, among other things, become a tool for improving the "technological design" approach (or solving technological problems) currently used in primary education programs. "Technological design", the purpose of which is the creation of objects or experiences to solve real problems, is not used enough and is poorly documented with respect to its optimal use. Design thinking would propose an innovative investigative process where some of its features enrich the usual “technological design” approach. In seeking solutions to local problems, problem solvers would benefit if they were to take advantage of design thinking: user empathy, abductive thinking, rapid and iterative prototyping, methods of evaluating solutions, and so on. Further, the teaching strategies suggested at the various stages of the design thinking process (examples: Empathy map, Journey Map, Participant profiles ...) would all constitute valuable and innovative tools in scientific education. Appendix 2 presents examples of small and large problems which learners of various ages could tackle using design thinking.

**Use of design thinking in education for sustainable development**

In education for sustainable development (ESD), the complex nature of environmental problems is a good fit for design thinking. This investigative approach produces more complete solutions since it requires learners to define complex problems from various angles (social, scientific and environmental), thereby allowing them to broaden the problem-space before seeking solutions (Pruneau et al., 2016). The implementation of design thinking in ESD contributes to the civic education of students or future teachers in keeping with the United Nations’ goals for sustainable development (United Nations, 2015).

The results of interviews with the organisations in this study and of field-testing show that design thinking does not always produce original solutions. However, if design thinking is properly implemented, it has the potential to promote collaborative work among problem solvers, to develop their interest in the issue being examined and to strengthen their high-level skills: creativity, empathic thinking, collaboration, critical thinking, self-efficacy, and problem solving. These latter skills are among the list of sustainability skills identified by Wiek, Withycombe, and Redman (2011).

But, how does one specifically adapt design thinking to education for sustainable development? At certain stages of design thinking, the addition of various teaching techniques is recommended. For example, during *Observation-inspiration*, problem solvers could be asked to frame the issue holistically by taking into account human needs and some non-human elements of the study environment (plants, animals ...) and by studying the quality and cleanliness of the surrounding environment (water, air, soil, economic resilience ...). The quality of social and physical environments is an important determinant of human health (World Health Organization, 2009). Further, tangible changes to the environment are often part of the solutions to human problems.

The first step in design thinking would be a good time for problem solvers to share their knowledge on sustainable development, that is to say knowledge relating to the issue (urban planning, climate change, plastics management, as the case may be ...). During the *Synthesis* stage, the visual depictions of the problem (networks of concepts, charts ...) and the framing of the conceptual challenge should take into account several aspects of sustainability (social, ecological, economic ...) and several objectives of sustainable development (in keeping with the United Nations, 2015). During *Ideation*, knowledge of the current trends towards sustainability in relation to the conceptual challenge can be shared among problem solvers as a source of inspiration and demonstrate that a movement towards sustainability is underway. The in-depth evaluation of solutions and prototypes might also be filtered using current knowledge on sustainable development and by forecasting the ecological, economic and social impacts of medium and long-term solutions.

Finally, when problem solvers work together remotely on the complex issues, collaborative digital tools (ICTs) could help them communicate and help them develop, structure and restructure their thinking, the way they frame the issue and their solutions. However, selected ICTs need to be age-appropriate and adapted to the numerical literacy of the problem solvers.

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**Photos Credits**

**Figures and Credits**

# Appendix 1

## Twenty organizations in design thinking that inspired this book

**Aardvark Design Labs** (San Francisco, United States):

The company works with a variety of partner organizations to develop the best products and experiences. Companies, teachers, and students participate in the design thinking workshops. The importance of the game is emphasized during the workshops.
**http://www.aardvarkdesignlabs.com/**

**Consulting Design Ltda** (Santiago, Chile):

The company works with a variety of partner organizations to develop the best services and experiences. In particular, it creates marketing and communication strategies for other companies. University students and faculty are also trained in design thinking strategies.
**http://www.cdesign.cl/**

**d.school - Institute of Design at Stanford University** (Stanford, United States):

This educational institution supports students in an interactive and innovative process that enables them to boldly and creatively tackle the most complex challenges and problems of contemporary society. The institution encourages the participation of students working in various fields, including engineering, education, medicine, administration, etc. For this institution, design thinking is a mix of engineering, design, arts, social science, and ideas from the business world. This institution also conducts research on design thinking.
**http://dschool.stanford.edu/**

**Design for Change** (Ahmedabad, India):

This is a global movement that began in 2009 at Riverside School, Ahmedabad, India, whose goal is to provide children with a platform to express their ideas for a better world and to put these ideas into practice straight away. Young people are introduced to design thinking and immediately apply their learning in their environment. The motto of the movement is, "Yes, we can!" Thanks to an annual creativity contest, the movement is now reaching 30 countries around the world.
**http://www.designforchangeindia.com/**

**Designathon Works** (Amsterdam, Netherlands):

The mission of this organization is to unleash the creativity of a million children on Earth and teach them to become agents of change for a better future. Their work is carried out through workshops, school programs and international competitions of creativity.
**https://www.designathon.nl/**

**Evangelische Schule Berlin Zentrum** (Education Innovation Lab) (Berlin, Germany):

This community school aims to empower and engage students in shaping a peaceful, just and socially and environmentally sustainable world for their future. Various community projects are underway to improve the environment. School staff receives training in design thinking. Students are trained in entrepreneurship.
**https://www.ev-schule-zentrum.de/aktuell/**

**Evergreen School** (Seattle, United States):

The private school teaches students to use design thinking to strategically define and solve problems that improve the lives of the school and the community. School teachers receive training in design thinking.
**https://www.evergreenschool.org/**

**Franklin Road Academy** (Nashville, United States):

Located in an inclusive Christian community, the private school is committed to developing honest and committed leaders. Design thinking is used to solve community problems with students.
**https://www.franklinroadacademy.com/**

**Hasso Platner Institute School of Design Thinking** (Potsdam, Germany):

This educational institution is interested in issues that arise continuously as society evolves. Its goal is to provide an opportunity for a diversity of students, emanating from a multitude of disciplines, to learn design thinking and then put it into practice by tackling the challenges and problems that characterize our complex society. The institution seeks to help students discover their potential for innovation and also conducts research on design thinking.
**https://hpi.de/en/school-of-design-thinking/**

**Henry Ford Learning Institute** (HFLI, Detroit, United States):

This organization creates and delivers programs to help students, teachers, and workers become more creative and resourceful in the way they think and learn. Its employees mobilize local and international partners to provide learners with the tools and skills to become empathetic partners and produce ideas to contribute to the well being of their schools, communities, and workplaces. Their approach aims to rethink learning methods through design thinking. The institute works closely with the Hasso Platner Institute School of Design Thinking to refine the process of design thinking in education.
**https://hfli.org/**

**IDEO.org (**San Francisco and New York, United States):

This pioneering organization uses human-centered design thinking to create products, services or experiences that improve the lives of people in poor and vulnerable communities.
**https://www.ideo.org/**

**INDEX - Design to improve life (**Copenhagen, Denmark):

This non-profit organization focuses on finding solutions to global challenges. They seek to inspire, educate and engage others in the design of solutions to global challenges. Each year, they launch a global competition (called the INDEX: Award), after which they present prizes to inventors of interesting solutions. INDEX also exhibits winning projects in world exhibitions and invests in the creation of solutions.
**http://designtoimprovelife.dk/**

**KIDmob** (San Francisco, United States):

The mobile firm conducts design thinking workshops with young people and teachers to solve real problems in various communities.
**http://kidmob.org/about/**

**MindLab (**Copenhagen, Denmark):

This intergovernmental innovation unit involves citizens and businesses in creating new solutions for society. It is also a physical space - a neutral zone to inspire creativity, innovation, and collaboration.
**http://mind-lab.dk/en/**

**Mount Vernon Institute for Innovation** (Atlanta, United States):

Through special events, training workshops and online resources, this team of nonconformist leaders helps schools, educational organizations and curriculum planners to transform their practices through human-centered design thinking.
**http://www.mvifi.org/**

**Punahou School** (Honolulu, United States):

The school teaches students to use design thinking in order to solve problems that improve the lives of the school and the community. It aims to adapt design thinking to Hawaiian culture. The school encourages a variety of ways for each student to live a meaningful life. Every child has unique skills that he must discover, develop and share with the world.
**https://www.punahou.edu/**

**Riverdale Country School** (New York, United States):

In this independent school, it is believed that the future belongs to those who adapt to new situations, ask good questions, try new ideas and work collaboratively with others. The idea is to create lifelong learners by developing students' spirits and characters and creating a community interested in improving the world. The school collaborated with IDEO to create the *Design Thinking Toolkit for Educators*, a teaching guide for the use of design thinking in education.
**https://www.riverdale.edu/**

**Sacred Heart School** (Saratoga, United States):

The private Catholic school builds the character of its students through faith, community service, and academic excellence. Through various experiences, students learn to become stewards of the environment and problem solvers, among other things.
**http://school.sacredheartsaratoga.org/school/index.html**

**St Aidan's Anglican Girls School** (Corinda, Australia):

The private Anglican school wants to develop and promote authentic, caring, confident, creative and connected women who value reason, imagination, honesty, compassion, and responsibility.
**https://www.staidans.qld.edu.au/**

**Workshop Education** (Hillsborough, California, United States):

This organization offers educational enrichment workshops after class. Simplified design thinking has been conceptualized for workshops for younger students, conducted in short, after-class periods.
**https://www.workshopeducation.org/**

# Appendix 2

## Ideas of problems to solve using design thinking

Brown (2009) points out that design thinking is an approach applicable to all challenges, be they personal, educational, economic, political, social, scientific, environmental, etc. In general, open, complex and wicked problems lend themselves well to design thinking. In education for sustainable development, conceptual challenges put to learners can affect the health, cultural life, economy, ecology or social characteristics of the community. Here are some examples of problems that could be presented to learners of all ages and to people in a community.

**Elementary or high school students:**

**Create…**

- Toys that encourage friends to play outside, to develop their environment, to understand various types of people, to protect species of all kinds ...;
- Ecological and practical bags to bring to school for sports activities or for carrying lunch ...;
- Recipes for using leftover food;
- Animal toys made out of recycled materials;
- Jewellery made from plastic bottles, wool remnants, old jewellery, coffee pods, corks ...;
- A rain garden (a spot where plants use excess water to grow);
- Shelters for small wildlife (bats, squirrels, hares, ruffed grouses, amphibians, oysters, fish ...) designed while considering their dietary needs and their protection;
- Birdbaths;
- Ways to green river banks;
- A salvage-box to redistribute warm clothing, toys, sports equipment and used baby equipment to other children;
- Seed pellets (balls of clay, containing seeds, which are thrown or deposited in places with little vegetation to improve biodiversity);
- A nature area where friends can relax and observe biodiversity;

- A composter made from used materials;
- A barrel for rainwater recovery;
- A distributor for wool remnants for bird's nests (birds will be able to find materials for netting their nest);
- Ecological packaging with recycled materials;
- A hedge to attract and feed bees, butterflies or birds;
- A shelter for useful insects: ladybugs, solitary wasps;
- A garden to feed hummingbirds;
- A spiral garden (containing plants that enjoy the sun or prefer the shade);
- Tasty meal menus that do not contain meat;
- A vertical garden (where plants grow on the interior or exterior walls);
- Ecological beauty and housekeeping products;
- Tools for rainwater recovery;
- Festive costumes made from used clothing;
- Ways to green the feet of urban trees, storefronts, homes for the elderly, parking lots, alleys, etc.
- For other problem ideas to solve with young students, see: http://www8.umoncton.ca/littoral-vie/empreintes.htm

**University students and community members:**

**Create…**

- New sources of income for a population (from sustainable natural resources);
- Adaptive measures to deal with the impacts of climate change: floods, droughts, erosion, heavy rains, heatwaves, cold ...;
- Climate change mitigation measures: carbon capture and storage; vehicles or modes of travel with low greenhouse gas emissions;
- Urban greening structures to improve life and biodiversity;
- Ecological plans for urban neighborhoods and vegetal strips along roadways;
- Slower modes of urban traffic;
- Modes of communication and a contingency plan for use in the event of an ecological disaster;
- Ways to clean or protect the water quality of streams and shorelines;
- Ways to restore or protect soil quality;

- Ways of assessing the quality of soil, water, air and the health of plants, humans, and animals;
- Scenarios to predict the many impacts of climate change in one's community;
- Ways to educate a given population on some aspects of sustainable development;
- Thematic community gardens: vegetable gardens, aromatic herbs, phytoremediation, anti-cancer plants ...
- Gardens meeting the needs of international students, the underprivileged, the sick, adolescents;
- Ways to help endangered species;
- Measures to restore marshlands;
- Laws to protect species or natural environments;
- Methods of collecting and recovering household waste;
- Methods of monitoring the quality of environments and natural resources;
- Modes of marketing and selling local products;
- Ecological products to replace pesticides, etc.

Appendix 3

## Resources for implementing design thinking

Websites**:**

**https://designthinkingforeducators.com/**

**http://www.designkit.org/**

**http://www.lucykimbell.com/LucyKimbell/Writing.html**

**https://dschool.stanford.edu/resources-collections/a-virtual-crash-course-in-design-thinking**

**https://dschool-old.stanford.edu/groups/k12/**

**https://dschool-old.stanford.edu/groups/designresources/wiki/4dbb2/**

**https://web.stanford.edu/dept/SUSE/taking-design/presentations/Taking-design-to-school.pdf**

**https://syn-lab.fr/wp-content/uploads/2017/10/Innover-a-plusieurs-version-longue.pdf**

**https://www.edutopia.org/blog/film-festival-design-thinking-in-schools**

**http://dlab.uky.edu/**

**http://www.projecthdesign.org/**

**http://www.iskme.org/services/action-collabs**

**https://www.fastcodesign.com/1663416/teaching-kids-design-thinking-so-they-can-solve-the-worlds-biggest-problems**

**https://soundout.org/meaningful-student-involvement-guide-to-students-as-partners-in-school-change/**

**http://www.democraticeducation.org/index.php/index/**

**http://tools.afsc.org/itsmylife/guide/itsmylife.pdf**

**https://fr.scribd.com/document/42672850/Creative-Workshop**

**http://etale.org/main/2013/03/03/27-resources-to-help-cultivate-design-thinking-for-educators/**

**https://www.oercommons.org/authoring/1686-design-thinking-for-11th-graders/view**

**https://web.stanford.edu/group/redlab/cgi-bin/publications_resources.php**

**https://static1.squarespace.com/static/57c6b79629687fde090a0fdd/t/58890239db29d6cc6c3338f7/1485374014340/METHODCARDS-v3-slim.pdf**

Vidéos

**https://www.youtube.com/watch?v=qqM8lf3zfFo**

**https://www.youtube.com/watch?v=ziADZVyLTqo&t=2s**

**https://www.youtube.com/watch?v=nyt4YvXRRGA&t=5s**

**https://www.youtube.com/watch?v=BG46IwVfSu8**

**https://designthinkingformuseums.net/2013/07/01/empathy-in-design-thinking/**

**https://www.thinkmind.org/index.php?view=article&articleid=achi_2015_3_10_20121**

Brainstorming: **https://www.ideou.com/pages/brainstorming**

Websites proposing sustainable solutions

DailyGood: **http://www.dailygood.org/**

Karma Kitchen: **http://www.karmakitchen.org/**

Karma Tube: **http://www.karmatube.org/**

ServiceSpace: **https://www.servicespace.org/**

Sustainable Everyday Project: **http://www.sustainable-everyday-project.net/**

Books

Brown, T. (2009). *Change by design: How design thinking transforms organizations and inspires innovation.* New York: Harper Collins.

Cross, N. (2011). *Design thinking: Understanding how designers think and work.* London: Bloomsbury Academic.

Day, G. S. (2007). Is it real? Can we win? Is it worth doing? *Harvard Business Review, 85* (*12), 110–120.*

Doorley, S. et Witthoft, S. (2012). *Make space: How to set the stage for creative collaboration.* Hoboken, New Jersey: John Wiley & Sons Inc.

Gallagher, A. et Thordarson, K. (2018). *Design thinking for school leaders: Five roles and mindsets that ignite positive change.* Alexandria, VA: ASCD.

Inc. OWP/P Cannon Design (2010). *The Third Teacher. 79 Ways you can use design to transform teaching & learning*. New York: Abrams Books.

Kelley, T. et Littman, J. (2001). *The art of innovation: Lessons in creativity from IDEO.* New York: Doubleday.

Kumar, V. (2013). *101 Design methods: A structured approach for driving innovation in your organization.* New York: Wiley.

Martin, R.L. (2009). *The opposable mind: Winning through integrative thinking*. Cambridge, MA: Harvard Business School Press.

Papanek, V. (2005). *Design for the real world: Human ecology and social change.* Chicago: Chicago Review Press.

Weinschenk**,** S. (2011). *100 Things every designer needs to know about people.* Berkeley, California: New Riders.