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**How Can Risk Science Contribute to Risk Education for Children
and Teenagers?**

Exploring Emerging Practices

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Abstract

Risk education is an emerging and interdisciplinary topic. Children and teenagers need risk education to enhance their abilities for decision making under the complex and uncertain conditions of today's world. Observations and performed practices have shown that various perspectives toward fundamental concepts of risk education resulted in a lack of a unified basis. The study aims to determine how risk science can contribute to risk education for creating a unified scientific basis. For this aim, the purpose is to know how the basic pillars of risk science are reflected in performed practices of risk education.

Participating at the international Risk Science and Decision Science for Children and Teenagers Conference in the Netherlands in 2018, Canada and the Netherlands were identified as the pioneers in performing practices of risk education. To gain more information, some relevant practices from some other countries were also examined. Semi open-ended interviews were conducted. Data were collected through interview responses as well as observations and discussions during the conference.

Results show that despite the fact that some fundamental concepts of risk science have been introduced to students in practices of risk education, they are not introduced or reflected sufficiently. While most of the practices in the Netherlands focus on fundamental concepts and technical risk assessment, they are not reflected in the practices of Canada or other countries. Moreover, in these practices, some of the basic pillars of risk science such as risk perception and risk communication have been neglected completely. Risk science can contribute to risk education by providing clear and systematic definitions and descriptions of fundamental risk concepts. Moreover, it clarifies the limitations of quantitative risk assessment by reflecting the principles of risk perception. Hence, risk education will be capable of improving children's and teenagers' abilities to have better communication skills and to have an active role in their society.

Key Words: Risk management, Risk Assessment, Risk education, Risk science, Risk communication.

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Chapter 1, Introduction

1.1. Motivation

Literacy is a human right and a prerequisite for the well-being of human (UNESCO: Belalcázar, 2015). It benefits people by making them less vulnerable to health risks, reduces poverty among them, and particularly enables women to gain their full potentials (Hanemann, 2015). Literacy contributes and helps to improve the quality of living for all communities, by strengthening individuals and families as small cores of a greater society. The definition of literacy can affect all relevant aspects of the literacy process from designed policies to the teaching curriculum. Regarding an operational definition in 2003, UNESCO defines literacy as “the ability to identify, understand, interpret, create, communicate, and compute using printed and written materials associated with varying contexts. Literacy involves a continuum of learning in enabling individuals to achieve their goals, to develop their knowledge and potential, and to participate fully in their community and wider society” (UNESCO Education Sector, 2004, p. 13).

Although literacy empowers people to have an effective role in complex situations, the question arises that whether traditional literacy is capable of enabling people to cope with the complexity of situations while making decisions. The inherent risk of new technologies makes life complex and ambiguous. People are confronted with a fast-paced changing life where every day a new technology is introduced and presents human life with new risks and uncertainties (Tauritz, 2016). On the other hand, authorities and decision makers try to implement optimal regulation and decisions to protect the society from plausible risks and hazards of this complex situation (Renn, 2008). The concern is whether it is easy to have literate people for effective participation only through top-down teaching and by means of traditional subjects.

A new perspective toward literacy with respect to risk and decision making is needed to make people aware of risks of new circumstances and to make them ready when it comes to making the right decision under newly introduced uncertain conditions. This is where risk education becomes essential. Risk education can contribute to people by enhancing their abilities in making optimal decisions from buying or selling stocks, to having an active role in their society for environmental and political decisions.

Participating in the international Risk Science and Decision Science for Children and Teenagers Conference in October 2018 in the Netherlands, it was revealed that there is a consensus on the need for risk education for children and teenagers among the experts, practitioners, and scientists from different disciplines such as risk science, decision making, policy making, and psychology. However, there are a lot of diverse perspectives toward the fundamental notions of risk as well as the content of the education. Risk science is the discipline that can underpin relevant requirements.

Among all countries, the Netherlands and Canada are pioneers and have ongoing experiences in the field of risk education. In the Netherlands, a project initiated in 2012 and primary school children were taught about the understanding of risk concept to see how they use this concept for decision making (Aven & Michiels Van Kessenich, 2019). The project initiated in pursuit of active citizenship and social cohesion by Dutch administration, which consequently had some impact on education. Accordingly, from 2005 based on a legislative proposal provided by the Dutch parliament, schools have some tasks to encourage active citizenship concept through education (Bron, 2010).

In Canada, to modernize the educational curriculum at schools, the British Columbia Ministry of Education started transforming education in 2010 to meet learners' needs efficiently (British Columbia, 2015; British Columbia Ministry of Education, 2012). One of the main principles of the guidelines for curriculum development was to address competencies implicitly in curricula to describe educated citizens. The curricula's aim was to enhance both cross-curricular competencies as well as specific subject competencies. These competencies and abilities, if gained, can positively contribute to individuals gaining efficient decision-making skills in uncertain and complex situations.

Risk education is an emerging topic and various perspectives toward it exist. In different contexts and countries, practices are performed differently. Risk education is multidimensional and the cooperation of experts from various disciplines is required. Studying the perspective of each of the involved disciplines can contribute to this emerging topic. An effective risk education needs a scientific basis which can underpin the unity and reliability. Risk science can provide a scientific approach through its core subjects for risk education to underpin efficient practices. The practices of risk education already performed are providing an appropriate space to reflect and discuss the contribution of risk science.

1.2. Objective

The main objective of the present thesis is to study the contribution of risk science to risk education for children and teenagers. This purpose is followed by asking how the basic pillars of risk science are reflected in academic practices of risk education.

In pursuit of the objective of the present research, performed practices of risk education in the Netherlands, Canada, and some other countries have been examined. It is the matter of interest to know whether basic pillars and fundamental concepts of risk science have been reflected in the basis of risk education completely, partly, or whether they have been neglected entirely.

1.3. Scope and Limitation

The present study discusses and explains the contribution of the risk science to risk education with respect to fundamental concepts and pillars of risk science. Risk science is a young field

and lots of discussions have been raised about the risk concept itself. Since risk science is multidimensional and includes various technical, psychological, social and cultural aspects, it would be out of the scope of the present study to examine details and factors of mentioned concepts.

Although a lot of definitions and descriptions for the risk concept exist, in this study the broadest concept of risk has been used and introduced which is capable of addressing different descriptions of risk. In addition, as risk science is multidimensional, discussions can be presented from other perspectives rather than the one presented here. Nonetheless, all discussions presented here are from the perspective of risk science and the goal is to have a broad perspective in consideration of the main pillars of risk science.

As the topic is emerging, few resources have been available for gathering data. Moreover, despite calling the performed practices as practices of risk education, not all of them are intended to fulfill risk education. As another point, with respect to the limited number of performed practices, the present thesis cannot study risk education for the specific children age group. Data is mainly gathered to examine the basics of risk educations.

Chapter 2, Literature Review

2.1 Risk Science

Risk analysis is a common topic of various disciplines and areas such as health, environment, industries, and technologies. With the advent of new technologies, risk analysis has significantly become a matter of concern for businesses and industries. Moreover, risk is one of the most important concerns of people and society. This is particularly true for those who are more vulnerable to economic loss, loss of lives and environmental damages while operators' negative externality is the main source of threats (Abrahamsen & Aven, 2012). Children are the future adults of the society who need to have improved skills for decision making under uncertain conditions and in cases of risk. Risk science can enrich risk education by providing relevant fundamental concepts and frameworks. Understanding of risk science theories and basic concepts underpin basis and reference of risk education curriculum (Russell, 2015). Accordingly, it is helpful to know about the foundation of risk science.

2.1.1. Foundation of Risk Science

Risk science, as a young field, has raised many discussions. "It is not broadly recognized as separate/distinct science" (Aven, 2018, p. 876). Nevertheless, it contributes to solving real life risk problems by means of frameworks, methods, and models in combination with knowledge from other disciplines such as statistics, psychology, and engineering.

The key principles of risk analysis are summarized in a document by Society for Risk Analysis (SRA) and provide a distinct risk analysis science as follows:

"Risk analysis covers two main types of knowledge generation:

- Risk knowledge (Knowledge type A) related to an activity (interpreted in a broad sense covering also natural phenomena) in the real world, for example, the use of a medical drug, the design of an offshore installation, or the climate.
- Knowledge of concepts, theories, frameworks, approaches, principles, methods, and models (Knowledge type B) to understand, assess, characterize, communicate, and (in a broad sense) manage risk" (Society for Risk Analysis, 2018b).

Aven provides a model to describe risk analysis science and the relevant types of knowledge generation (Figure 1.1) (Aven, 2017). The interaction between A and B types of knowledge is visible in this model.

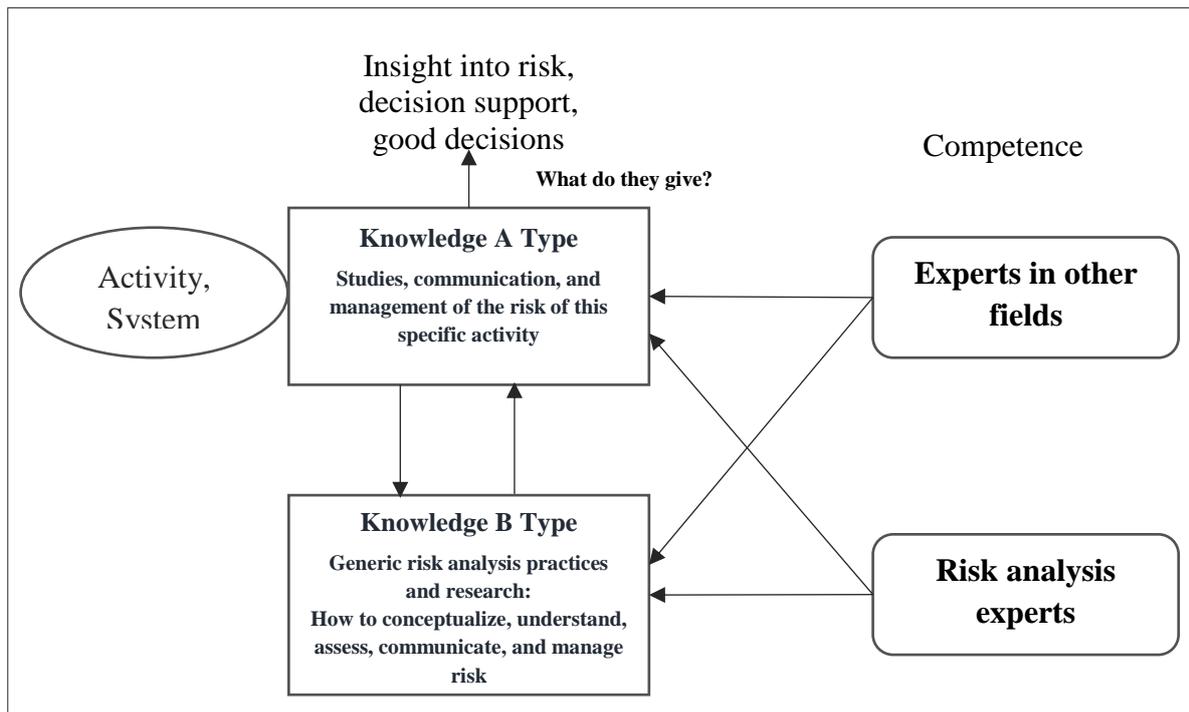


Figure 1.1. Model for Describing the Risk Analysis Field (Aven, 2017, p.858)

The model illustrates the contribution of risk science to risk related issues in real life activities (such as education, climate change, health and pharmaceutical risks, engineering and psychology) through knowledge type A. To generate this type of knowledge, risk analysis principles, approaches and experts cooperate with experts in other fields (e.g. psychologists, statisticians, policy makers, etc.) and support relevant studies, communication and management of the risk for a specific activity (Aven, 2017).

In addition, generation of knowledge type B develops risk analysis science through relevant concepts, frameworks, methods, and approaches. Hence, knowledge type B contributes to conceptualizing, understanding, assessing, communicating and managing risk for real life activities. For this, in addition to risk experts' knowledge, support from experts in other fields is essential. Knowledge type B also includes relevant concepts such as risk, probability and uncertainty (Aven, 2017).

In a nutshell, risk science can contribute to risk education by means of basic concepts, theories and frameworks in cooperation with other disciplines. Although mentioned concepts in knowledge type B may seem basic, their contributions are important for risk analysis in real life activities. Therefore, it is helpful to understand these concepts.

2.1.2. Risk Communication and the Need for Risk Education

Risk communication has emerged as a central concern that impacts risk management and risk assessment. Risk communication plays an effective role in successful risk management and

decision making (Renn, 2008). Effective communication can help people to better comprehend uncertainty and risk. Hence, their capacity and the ability for dealing with risk can be changed.

When it comes to risk communication, principles of communication itself becomes important. What is important in risk communication, like other areas of communication, is the notion and characteristics of the content as well as senders' and receivers' abilities and characteristics. Effective communication can contribute to how people are prepared to understand and cope with the uncertain outcomes and risks (Renn, 2008) and hence their decision making can be affected as well.

The purpose of risk analysis is supporting decision making when the situations are, to a large extent, uncertain (Aven, 2012). Particularly, in cases where the consequences are uncertain and have severe outcomes, decision making can become a difficult process. When there is a problem to decide, there are often various alternatives in addition to concerns about the outcomes. To make an optimal decision, tradeoffs should be understood for the problem, its relevant causes and consequences. This becomes possible by having a good understanding of uncertain situations. This is where risk communication plays the key role. Therefore, although risk assessment can support decision making, people's understanding of the content of communication matters.

People's knowledge and awareness of the concept plays an important role in such communications. Hence, less knowledgeable people are more vulnerable to being misunderstood. Therefore, the potential for failure of the communication can be higher in these cases. Therefore, communicators emphasize educating people about the content of risk communication.

Accordingly, among the functions of risk communication, risk analysts mention two major functions for improving people's risk communication abilities; they are (Renn, 2008, p. 203):

- “Education and enlightenment: inform the audience about risks and handling of these risks, including risk and concern assessment and management.
- Risk training and inducement of behavioral changes: help people to cope with risks and potential disasters.”

Educating and training people about risk has been emphasized through these two functions of risk communication. The accomplishments are not only for people, but also for the risk professionals who are involved with public concerns in addition to risk analysis results for decision making. Renn emphasizes that risk communication can be regarded as a mutual learning process where on one side there are people with concerns, perceptions and experiential knowledge who can affect the risk professionals on the other side (Renn, 2008).

Regarding the subject of the present study, the two aforementioned functions of risk communication usher us to risk education which in continue will be examined and discussed.

However, it would be helpful to understand the notion of risk before starting a risk education discussion.

2.1.3. Definition and Description of Risk

There are several definitions and descriptions for risk concepts. Among them, risk is “the expected loss; a measure of the probability and severity of adverse effects; combination of probability and extent of consequences; a situation or event where something of human value (including humans themselves) is at stake and where the outcome is uncertain; the effect of uncertainty on objectives; the two-dimensional combination of events/consequences and associated uncertainties; uncertainty about and severity of the consequences (or outcomes) of an activity with respect to something that humans value” (Aven, Renn, & Rosa, 2011).

Gigerenzer defines risk as “a probability of an event that is measurable” (Eichler & Vogel, 2015, p. 169). Spiegelhalter finds risk uncertain and refers to both good and bad outcomes of risk (Spiegelhalter, 2008). Variety of definitions for risk concept and absence of clarification for relevant concepts make some obstacles for using them (Eichler & Vogel, 2015). This can become problematic in generation of knowledge type A. Therefore, it is essential to have a unification on terminology for having a scientific foundation in the field and SRA provides such unity (Aven & Michiels Van Kessenich, 2019). Risk terminology is important as it reflects the underlying thinking and can significantly influence how the risk concept is understood and communicated (Aven, 2018).

The definition of risk used in this research is as below:

“Risk refers to uncertainty about and severity of the events and consequences (or outcomes) of an activity with respect to something that human value” (Aven & Renn, 2010, p. 8) (Figure 1.2).

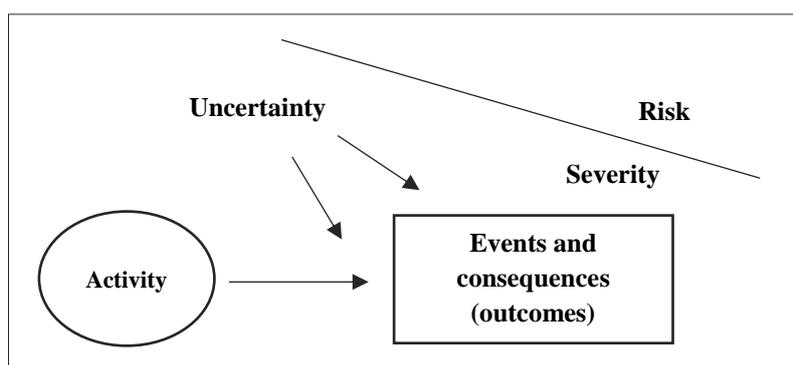


Figure 1.2. Illustrates of the risk definition (Aven & Renn, 2018, p. 8)

This definition of risk introduces two features; the uncertainty of the events or consequences of an activity and the severity of them (e.g. the size or extension or other measures of magnitude regarding something humans value) (Aven & Renn, 2010). To clarify the effect of risk, references (such as desirable criteria or objectives) are always important and different

references give different risks (Aven & Michiels Van Kessenich, 2019). The magnitude of the outcomes with respect to the references presents the severity of the outcome. As an example, for a teenager, one of the risks can be defined as uncertainty about the consequences of smoking marijuana (e.g. addiction) and the severity of them.

This definition introduces a broad perspective toward the notion of risk with two dimensions, the uncertainty and the severity of the consequences with respect to the values. Risk cannot be judged only on the basis of a measure of uncertainty, the severity must also be taken into account (Aven & Renn, 2010; Rosa, 1998). It is noticeable that probability is just one of the tools for predicting or expressing uncertainty.

This definition of risk also covers the dimensions of the risk concept defined in the basic pillars of risk science as consequences with respect to something that humans value which is also uncertain (Aven, 2018).

Despite the existence of diverse definitions for the risk concept, this definition reveals properties such as (Aven & Renn, 2010):

1. Both positive (desirable) and negative (undesirable) consequences are addressed.
2. The emphasis is on uncertainties and not limited to probabilities and expected values.
3. All outcomes at stake are covered and not only particular ones.

Such properties provide a broader perspective for students beyond doom and gloom of risk since they show that it will be possible to develop opportunities and avoid undesirable outcomes.

In the context of risk, two types of uncertainties are discussed by risk analysts;

- Aleatory uncertainty: refers to variability in known populations and shows the randomness in the sample (Paté-Cornell, 1996). An example of this type can be rolling a fair dice. Although randomness and variety can be seen in the results, having a large sample in the long run results in revealing of distribution of outcomes. To express aleatory uncertainty, frequentist probability is used
- Epistemic uncertainty: refers to lack of knowledge about phenomena (Paté-Cornell, 1996). For instance, climate change issues or overpopulation are accompanied by epistemic uncertainty where the uncertainty can be reduced by the improvement of relevant knowledge. for epistemic uncertainty, (subjective) knowledge-based probability is used.

It is noticeable that probability is just one of the tools for expressing uncertainty. Making distinction between risk definition and its measurement tool is important and if such a distinction is not considered, lack of understanding of risk would be the result. Risk should be captured beyond probabilistic quantities (Aven, 2018).

Moreover, using probability in risk analysis without explaining its meaning provides poor basis results in imprecise and erroneous outcomes. It is essential to clarify whether probability is

used to either show variation (frequentist probability) or an analyst's degree of belief (subjective probability). There are a lot of materials available for the frequentist and Bayesian probability approaches in risk context which is helpful for better understanding of risk assessment (Aven, 2015, 2018; Aven, Baraldi, Flage, & Zio, 2014).

Considering risk communication, probability alone is not enough for informative risk communication. Numbers are not enough for communication of risk or informing people about a decision (Fischhoff, 2012). As mentioned before, for effective risk communication, risk education will be helpful.

2.2 Risk Education

2.2.1. Risk Literacy

Reading and writing abilities play important roles for informed citizenship, however, Gigerenzer argues that these abilities are not enough for people in today's high-tech world (G. Gigerenzer, 2011). Risk literacy is also needed which can help people to make informed decisions and manage uncertainties. Without risk literacy, people's health, money, and even emotions are endangered and jeopardized (Gigerenzer at TEDxZurich, 2013). Risk literacy is the tool used to interpret and use data accurately for efficient decision making in cases of risk and uncertainty; something that the general public lacks (Galesic & Garcia-Retamero, 2010). For instance, in terms of health relevant information, understanding and communicating risk and benefits of decisions based on numerical concepts are usually problematic for people (Reyna, Nelson, Han, & Dieckmann, 2009). Risk literacy is also very important in financial context; however, research shows that people have inadequate knowledge about risk, which can affect their financial literacy (Lusardi, 2015). During the financial crisis, many people lost their homes as a result of inappropriate financial decisions in uncertain cases. On the other hand, risk literate people tend to save, plan and make decisions for future investment more efficiently. It is less probable for risk literate people to invest in high cost borrowing (Lusardi & Mitchell, 2014). To utilize risk literacy, it is necessary to understand what it means.

To define risk literacy, Riechard states risk-literate people are the ones who "have the knowledge, objectivity and inquiry skills that makes it possible for them to interpret ...[risk-related] information presented in popular media..." (Riechard, 1985, p. 9; 1993, p. 110) and that "...they are critical thinkers and decision makers; they ask questions, seek answers, study consequences, and act on the basis of the best information" (Riechard, 1985, p. 9; 1993, p. 110). The aforementioned definition refers to personal skills and abilities of people, which when improved, enhances individual and social life quality. As another definition, "risk literacy refers to one's practical ability to evaluate and understand risk in the service of skilled and informed decision making" (Risk Literacy, 2019). Having appropriate skills and abilities for informed decision making allows people to have better control of their lives and its aspects such as health, environment and finance. Moreover, improved decision-making gives

individuals the ability to contribute to healing the crises of society. By means of risk literacy, people find the ability to participate actively in their social, cultural, political, economic issues, which are aligned with purposes of literacy (G. Gigerenzer, 2011).

Risk literacy has been largely conceptualized as being about numeracy. It can be achieved through the improvement of statistical thinking which is the ability of understanding and critical evaluation of uncertainty and risk (G. Gigerenzer, 2011). Teaching statistics to students at schools involves them directly solving real-life problems (such as health issues like cancer or pregnancy and financial issues like investing or bankruptcy). Statistics and probabilities are main features of risk assessment (Cokely, Galesic, Schulz, Ghazal, & Garcia-Retamero, 2012). Therefore, probabilities and statistics play major roles in risk assessments and decision making such as health and environmental risks. Moreover, statistical information can affect risk analysis and risk communication (Risk Literacy, 2019). It has been found, with regards to health decisions, despite existence of individual differences in understanding numeracy, statistical numeracy plays a significant role in risk communication and decision making (Lipkus & Peters, 2009).

Statistical misunderstanding is not limited only to lay people and mass media. There are many cases where physicians misunderstood the likelihood of patients' cancer after a positive test. This matter itself is problematic. Therefore, it is essential to motivate and teach all people about risk literacy. Accordingly, it is suggested to teach statistical thinking as well as its concepts at early years of education to familiarize children with probability and utilizing it to solve real-life problems (G. Gigerenzer, 2011; G. Gigerenzer, Gaissmaier, Kurz-Milcke, Schwartz, & Woloshin, 2007).

2.2.2. Numeracy (Probability) Literacy

Numeracy generally has been defined as the capabilities of communication and problem solving that everyone needs for managing relevant situations (Gal, 2000). Accordingly, three main types of numeracy are mentioned, which involve computations, interpretations, and decisions that are relevant to probability literacy (Jones, 2006).

Despite the existence of obstacles for teaching risk mathematically, teaching numeracy plays a significant role in improving risk literacy which supports the skill of informed decision making (Eichler & Vogel, 2015). Numeracy provides the main contribution for improvement of risk literacy and decision making under uncertain conditions, which is essentially the ability of processing probability and statistical concepts (G. Gigerenzer, 2011; Peters et al., 2006). In the health context, for example, the ability to use probabilities and statistical literacy have been referred to individual competencies relevant to health literacy (Ancker & Kaufman, 2007). Hence, probability becomes important by affecting how and what information is used and interpreted for decision making (Lipkus & Peters, 2009). Research shows that highly numerate people can be less affected by the framing of numerical information (Peters et al., 2006). In

this regard, it would be useful to know what people are supposed to learn from probability and statistics and in what way they can be helpful for the improvement of risk literacy.

Gal and Garfield explain the conditions needed to become an informed citizen by means of statistical education which is to “comprehend and deal with uncertainty, variability, and statistical information in the world around them, and participate effectively in an information-laden society” (Gal & Garfield, 1997, p. 3). This goal points to the main aim of risk literacy which emphasizes informed decision making under uncertain conditions. To achieve this goal, eight sub-goals based on a few key ideas have been introduced, among which is sub-goal number 5 which is understanding probability and chance and number 6 which is developing interpretive skills and statistical literacy. One of the basic ideas of understanding probability and chance emphasize on understanding that probability is a measure of uncertainty (Gal & Garfield, 1997, p. 4). The idea recalls the risk description the uncertainty is one of the main dimensions of risk definition and probability is one of the ways for this measurement. Moreover, sub-goal number 6 refers to the improvement of students’ ability to interpret the information and use them for critical thinking and not just as consumers of data and information.

Risk communication is another aim of probability literacy. Spiegelhalter and Gage introduce risk communication and explanation of uncertainties to the public as the essential elements of probability and statistics literacy (Spiegelhalter & Gage, 2015). They explain it as a difficult topic to teach. Moreover, Gal refers to it as the ability to “communicate probability related information and ideas in order to engage and effectively manage the demands of real-world roles and tasks involving uncertainty and risk” (Gal, 2012, p. 4). However, teaching probabilities is not without difficulty. To tackle such difficulties, taking some ideas into teaching such as natural frequencies, expected frequencies and frequency trees have made complex probability understanding more comprehensible (Spiegelhalter & Gage, 2015).

Individuals need the ability to interpret or generate probabilistic messages. Literacy in probability can enhance their abilities to critically evaluate statistical results for decision making in real life situations. Critical questions are among the basic elements of probability literacy which support critical thinking for making an informed decision (Jones, 2006).

Three levels are described to enhance this literacy; basic understanding of probabilistic and statistical terminology, understanding of statistical language and concepts when they are embedded in the context of wider social discussion, and the ability to apply a questioning attitude to statistical claims and arguments (Jones, 2006, p. 45). These levels refer to the importance of the context in applying probability literacy as well.

In a nutshell, being numerically literate contributes to the enhancement of critical thinking abilities to interpret and scrutinize real life problems under uncertain conditions. Hence, informed decision-making turns citizens into empowered informed citizens who can integrate actively with the social environment.

In emphasizing risk literacy, it is suggested to combine risk education into school curricula (Riechard, 1993). Regarding health and environmental risk decisions, Riechard suggests that risk education can raise citizens as critical thinkers whose decisions are based on utilizing their abilities to interpret information, asking questions, seeking answers and studying consequences (Riechard, 1985). Risk education is a topic that must be discussed thoroughly.

2.3. Development of Risk Education

The idea of risk Education essentially reflects concerns about citizens and relevant health and environmental risk (US. EPA. Science Advisory Board, 1990). Citizens' focus on specific types of risk is followed by risk management resource allocation for relevant risk mitigations by government agencies and private sectors. Accordingly, recognition of major risks by citizens, which may bring significant effects to citizens' lives is notable (Zint & Peyton, 2001).

In this regard, Briscoe believes that education and adoption of national standards by improving citizens' abilities in decision making could function more efficiently than trustworthy management, not only economically but also as a matter of safety (Briscoe, 1992). He encourages risk experts to help students understand risk perception factors and use risk reducing measures to increase their safety (Briscoe, 1992).

To operationalize risk education in an environmental context, the superordinate goal of risk education has been defined to develop capable and responsible citizens who will make important personal and social decisions based on a thoughtful analysis of health or environmental risk information (Zint & Peyton, 2001, p. 3). However, risk education has only been considered as various types of hazards (e.g. fatality, injury, etc.).

In addition to environmental and ecological risks, there are other significant challenges that show a need for risk education in today's world. In this regard, the unmeant consequences of globalization and modernization have appeared as global risks (Huang, 2015). Social risks such as bullying, using drugs, road safety, terrorism, poverty and social media are pervasive and formal education can enhance students' competency in risk evaluation (Bardsley, 2017). Water scarcity is another risk that can affect the world population, food and agriculture unless understanding of relevant individual or societal risk is improved (Orr, Cartwright, & Tickner, 2009). Children's lifestyle and health are at the exposure of media risk which confirms the essential of relevant education (Kline, 2005). In the pharmaceutical sector, for instance, some citizens perceive vaccination as a risk and oppose it, where systematic education and training can be helpful (Davis et al., 2002; Sherris et al., 2006). In the uncertain and ambiguous conditions of various risks, improved skills and competencies are needed for efficient decision making.

There exist mirids of instances that confirm the complex nature of the society in combination with the sheer amount of uncertain and ambiguous information which is insufficient for people for efficient decision making (Tauritz, 2016). At this point, to deal with ambiguous conditions,

the role of education becomes vital to facilitate people and citizens with appropriate skills and abilities. Formal education systems can support students by addressing relevant curriculum for social and ecological risks and engage them to relate their own lives and curriculum concepts (Bardsley, 2017).

For decision making under uncertain conditions and to develop individuals' abilities, it is required to enhance their uncertainty competences through relevant skills and knowledge. Therefore, education should and can prepare people for decision making in case of overwhelming uncertain situations based on incomplete and imperfect information which is almost always the case (Tauritz, 2016).

2.3.1 An Early Practice of Risk Education for Children

An early project was developed between 1974 to 1980 in the School of Education at Hebrew University of Jerusalem, for improving students' probabilistic thinking skills and understanding of the uncertainty concept (Beyth-Marom & Dekel, 1983; Beyth-Marom, Dekel, Gombo, & Shaked, 1985). The project conducted was based on two main trends; teaching of thinking which was focused on principles of logic, critical thinking, problem solving and everyday reasoning (Beyth-Marom et al., 1985) and psychological studies of cognitive processes (Kahneman & Tversky, 1974). The result was the development of a curriculum called Thinking Under Uncertainty for fourteen-year-old students to enhance their abilities to think about uncertainty.

The curriculum aimed at thinking under uncertainty to deal with cognitive limitations in perceiving uncertainty, processing information, evaluating risk and judge decision quality (Beyth-Marom & Dekel, 1983). While in reality, people cope with such limitations through developing a simple thought process, called heuristics, such a process may lead to failure due to the limitation of memory in memorizing, retrieving and prioritizing that result in bias estimation of frequencies and probabilities of events (Kahneman & Tversky, 1973). To avoid the systematic biases following people's intuitive judgment, the curriculum is an effort to show students how and when their judgment can be wrong as well as presenting corrective procedures for improved inductive reasoning (Beyth-Marom & Dekel, 1983).

The approach used in the curriculum was also reflecting intuitions as it was believed that to teach thinking skills, thinking itself must be the priority. It is discussed that the traditional approach for judgment under uncertainty are normative tools such as statistics and probability which have not been successful enough for real-life problems out of classrooms. The curriculum was designed as a 35 to 40-hour instruction for 9th-grade students who are able to understand the more complex thought process and uncertainty concept (Beyth-Marom & Dekel, 1983).

The curriculum was set as a textbook including three main sections. The first section provided a general framework for thinking about uncertainty. The second section provided some tools to deal with the problems under uncertain conditions, and the third one particularly focused on

the probability assessment. However, students were not the only group involved with this curriculum. During the development of the project, some teachers were trained too. Indeed, the way teachers comprehend the topics would affect their interaction with students while dealing with the curriculum (Beyth-Marom & Dekel, 1983).

Finally, it is emphasized that teacher training and curriculum evaluation are two important issues that should receive special attention (Beyth-Marom & Dekel, 1983). While debiasing techniques and useful approaches for improving quantitative estimates have been provided, the authors state that the curriculum needs more work and evaluation.

Reviewing academic studies, most of the available practices of risk education have been performed in a specific context such as environmental health, decision making, physical safety, and critical thinking skills. Rather than focusing on children and students, some studies focus on teachers to explore their perspectives about risk education. However, risk concept, definitions, and approaches toward teaching risk vary with respect to the teaching context.

2.3.2. Risk Education for Physical Safety

One of the aims of risk education for children, as well as adults, is to improve their ability to avoid life threatening situations which can result in temporary or permanent physical damages. Parts of the study about risk education are dedicated to this area to improve children's knowledge about uncertain situations and risks. In continue, some relevant literature will be presented.

Studies show that to improve children's knowledge and ability for interpreting data in risk situations and avoiding risks, education and intervention can be helpful. In this regard, some practices show that children's understanding and abilities to interpret dog signaling can be improved by training and hence, by improved correct safety decisions the risk of suffering from dog bites can be reduced (Meints, Brelsford, & Keuster, 2018; Meints & Keuster, 2009). The aims of these practices are to investigate children's ability to judge safety messages as well as exploring their perception of dogs' body language and then improving their knowledge and interpretation skills by training them through using video intervention. The results show that training children under 7 have significantly improved their abilities in interpreting signals, judging risky situations, and avoiding risks or escalation of potential risks particularly for high risk situations. Moreover, the learning effects last over time which facilitates children with better abilities to deal with the risk situation and make safer choices interacting with dogs (Meints et al., 2018; Meints & Keuster, 2009).

In the context of the media, Kline discusses that media and mass advertisement as important risk factors can increase the risk of unhealthy food consumption, obesity and aggressive behaviors for children in the long run. In this regard, it is mentioned that educating children about relevant risk can help them to make efficient choices for their leisure times and lifestyle which result in decreasing relevant risks. A framework for media-risk education strategy has been provided which provides the basis of making informed decisions. In this research, risk is

defined as anything that increases the probability that a person will suffer harm and hence there should be some protection for that (Kline, 2005).

2.3.3. Risk Education and Decision Making

Decision making abilities play a significant role in people's lives while choosing a specific choice can completely change their future. In this regard, teenagers' decision-making abilities are also a matter of concern.

To improve teenagers' decision making abilities, a video intervention program has been developed to provide an effective educational program in sexual health context for reducing risky sexual behavior and sexually transmitted infections among them, in the United States (Downs, Bruine de Bruin, Fischhoff, & Murray, 2015). Unlike most ineffective sex education programs, this program is based on the mental model approach which can provide a disciplined basis to address different concerns of the risk to be reduced. The video intervention program includes various aspects of sexual risk management such as cognitive, social, and emotional ones. Therefore, viewers are provided with the necessary information and skills for decision making and facilitated with some strategies while they are confronted with social pressure. The result of a randomized controlled trial of the program illustrates a reduction in risky sexual behavior and acquisition of chlamydia infections which can contribute to young teenagers for choosing acceptable decision strategies (Downs et al., 2015).

As another effort, Decision Education Foundation (DEF) provided a summer course, titled Essential Decision skills, for high school students to teach them how to make better decisions for better lives. The course curriculum included four parallel phases; a framework that includes the basic values and ideas of the course, personal and interpersonal skills, correct reasoning, and process of teaching. Various methods have been used in the course, such as video clips, case studies, literary examples, group projects, hypothetical characters, tools for probability encoding, and role-play. The result of this practical experience showed that students' opinion about the usefulness of the course has changed at the end of the course in comparison to sign-up time. In this regard, the mean score of the course has been evaluated 7.6 by students with the scale from 1, which means a waste of time, to 10 which means an exceptional course (Abbas, Reiter, Spetzler, & Tani, 2004). The study focus was on curriculum development for decision making. Risk education or risk concept in this study has not been addressed explicitly. However, it hints the critical thinking concept by engaging students in activities and activating their wills and abilities for decision making. Moreover, using decision analysis tools such as decision tree and the concept of the value of information (VOI), in combination with games and literature examples show that the risk concept has been introduced beyond hazards and dangers in this practical experience.

Zint and Peyton provide ten main goals for risk education. Accordingly, risk has been defined as "the probability that harm will occur" (Zint & Peyton, 2001, p. 47). However, the final ten risk education goals refer to risk definition as something more than the probability of hazard

occurrence. This is confirmed by one of the goals which emphasizes necessary skills for the students to interpret calculated probabilities. Moreover, psychological aspects of risk education have been considered through goals such as evaluation skills for risk perception, personal biases in risk judgment, and the importance of risk communication. The authors believe that being informed about risk assessment per se cannot efficiently improve citizen's abilities for decision making (Zint & Peyton, 2001). These goals can explicitly refer to the broader risk concept and definition which go beyond risk as a matter of problem or doom and gloom.

2.3.4. Environmental Risk Education

Environmental context is the context which has received the most attention for risk education since people are at the exposure of environmental health risk such as global warming and pollution.

With a focus on environmental context, Covitt et al. evaluate the outcome of a specific risk education module (Covitt, Gomez-Schmidt, & Zint, 2005). The results show that students' risk knowledge has modest improvement through implementing modules while self-assessed risk knowledge has shown stronger improvement. Competency enhancement has not happened in students' sense of responsibility or their perception to manage risks. Though the module has been found as a helpful learning experience by the teacher, some suggestions have been provided. One of them is to provide a framework for students for decision making in the environmental context. Moreover, as an interdisciplinary field, there is a need for interdisciplinary group cooperation for risk education activities (Covitt et al., 2005).

In Australia, a study about teachers' opinions of risk education in geography demonstrates that some teachers are concerned with the deterioration of students' perspectives by risk education considering potential drawbacks and negative impression of it (Bardsley, 2017). Accordingly, contrary to some teachers who find risk education helpful for students and have a positive perspective towards risk education, some others believe that risk education has some disadvantages followed by doom and gloom for students. The level of negativity of the term risk for some teachers is so high that they avoid using it during their teaching. It is argued that students need to get familiar with the term risk as a motivator or creator to make them able to solve the problems, and hence become active citizens (Bardsley, 2017). An efficient framework that can reflect the risk concept, its definition, and its aims can be fruitful for all involved groups in this emerging interdisciplinary field.

2.3.5. Improving Critical Thinking Ability

To contribute to risk education, Gregory defines Critical Thinking as an important skill to improve children's abilities for distinguishing automatic thinking from decision thinking and consequently making efficient decisions and decreasing health risks. Three key elements have been provided for critical thinking; defining a decision perspective, making choices under uncertainty and thinking about consequences. To implement these elements in the classroom, some procedures have been provided. Critical thinking skills do not intend to provide a right

or wrong answer to uncertainties but contribute to balance opportunities and losses of uncertain outcomes when making a decision in a risk situation (Gregory, 1991).

Critical thinking skills along with competencies such as communication, positive personal and cultural identity are considered as core competencies of redesigned British Columbia curriculum and have been incorporated through value-based decision-making framework to teach 10 to 13-year-old students for better understanding of their values and perspectives in decision making (Vogel, 2018). A model of the discussed decision-making framework, named ProOACT consisting of the steps Problem, Objective, Alternatives, Consequences, and Tradeoffs, is used for a better understanding of one's interests and values (Vogel, 2018). Regarding the steps Consequences and Tradeoffs, the framework is to contribute to improving understanding of uncertainties and risks. It is important to unveil uncertainties and balance outcomes of risks for every decision. It emphasizes the significance of risk education for decision making implicitly. The aim of this project is to provide a toolkit for understanding the key components of value-based decision making through gamification by engaging students with a collaborative and cooperative learning process (Vogel, 2018).

Michiels van Kessenich and Geerts explain that frequently, professionals and people in society express risk as probability times consequences and this becomes a starting point for them to feel worried about uncertain consequences (Michiels van Kessenich, 2017). It is stated that "this uncertainty conceptualized as a problem (instead of a lamentable but unfortunately unchangeable given) then leads to confusion, frustration and to an increased unwillingness to use risk-based approaches as a way to organize available information and aid decision-making" (Michiels van Kessenich, 2017, p. 5). Despite the dark side of the risk, there also exist benefits that can be determined through risk education and result in effective critical thinking and efficient decision making. In pursuit of this broad risk perspective, Michiels van Kessenich and Geerts teach concepts such as risk, chance, and real risk in society through engaging 10 to 12-year-old students with games and open discussion (Michiels van Kessenich, 2017). Results of the immediate and long-term (nine-month) evaluation of their practices show positive effects on the students' understanding and effective ability about risk concept. Increasing students' level of knowledge about risk concept can bring them improved personal skills and abilities for efficient decision thinking.

2.3.6. Summary

Thus far, various studies have been reviewed in which risk has been taught to students in various contexts. Various definitions of risk and different approaches towards that have been used in discussed studies. The studies have targeted either students or teachers for risk education. Sometimes, the hazardous side of risk has been emphasized while in some cases there has been no implicit definition of risk. Obviously, discussed studies lack unity. What and how risk is defined or perceived plays a significant role in the provision of risk education. Russell states understanding of theories of risk analysis provides a basis and reference for risk education curriculum (Russell, 2015). Understanding the notion of risk and coming to a

consensus on that can be helpful for all involved groups. In addition, preparing relevant curriculum and frameworks results in efficient decision-making skills. Hence, teaching about the risk concept becomes sensible without making confusion for learners (Michiels van Kessenich, 2017).

Chapter 3, Aim and Methodology

3.1. Aim

Risk science plays an important role in risk education. For a proper risk education, a proper understanding of risk science is needed as well. For this aim it is necessary to know about the constituents of risk science (Aven & Michiels Van Kessenich, 2019).

Although some practices of risk education have been done around the world, it seems that the fundamental concepts and basic pillars of risk science have not been fully taken into account. There is a need for a unified framework as an underlying foundation for risk education. The main focus of this research is to answer how the basic pillars of risk science are reflected in academic practices of risk education. It is hypothesized that despite some fundamental concepts of risk science being introduced to students in performed practices of risk education, they are not introduced or reflected sufficiently in the basics of those practices. Moreover, some of the basic pillars of risk science have been neglected completely in performed practices of risk education.

3.2. Methodology

To describe, interpret, and gain an in-depth insight into the objective of the present research, qualitative methods have been used. Data was collected based on systematic review of the documents, participatory observations, and targeted interviews.

Participatory observations were done during the week-long at the international Risk Science and Decision Science for Children and Teenagers Conference at Lorentz Center in the Netherlands, in 2018. Participants were experts, scientists, and practitioners from different countries and disciplines such as risk science, decision making, policy making, and psychology. Data were registered by note taking during the workshops, group discussions, and presentations at the conference. In addition, the target groups for the interviews were identified.

We have identified the Netherlands and Canada as the two countries that have the ongoing experience of risk education. They have emerging practices that seem to be the best pilot practices amongst all other countries. The purpose is to analyze and explore these pilot practices as the best ongoing practices rather than performing a structured analysis of the education systems. Moreover, we scrutinized performed practices in some other countries, the United States, Norway, and Germany, to gain in-depth information for studying our objective.

Semi open-ended interviews were conducted since the perspectives and definitions of the concepts were diverse. These interviews provided more in-depth insights into the performed practices and their underlying perspectives. Since the topic is emerging and the practices are not many, seven interviewees participated in the interviews. The participants were the experts

and practitioners from the mentioned countries with different backgrounds, careers, and professions who have been engaged with the performance of the practices. Refer to Table 3.1 for a list of participants.

Table 3.1. Coding for Interviewees

	Profession	Field	Country
Practitioner 1	Teacher	Teaching decision making and risk	Canada
Practitioner 2	Researcher and part-time civil servant municipality	Risk Analysis	The Netherlands
Practitioner 3	PhD Candidate, Former HSE advisor and risk assessor	Public health, Faculty of Health Sciences	Germany
Expert 1	Researcher	Risk analysis	The Netherlands
Expert 2	Professor	Teacher training; Teaching Geography	The Netherlands
Expert 3	Professor	Social psychology	The United States
Expert 4	Professor	Psychology; Children's physical development by risky play	Norway

Ten questions were developed for collecting data. The supportive source of the questions was mainly the basic pillars of risk science (Aven, 2018; Society for Risk Analysis, 2018b). Refer to Tables 3.2 and 3.3 for a summary of these questions.

Core subjects and basic pillars of risk science consist of the main categories mentioned below. Considering that these categories can provide a platform to identify and trace main subjects for risk related activities in real world, and in our case risk education.

The aforementioned main categories are as follow (Aven, 2018; Society for Risk Analysis, 2018a):

1. Fundamental concepts
2. Risk assessment
3. Risk management
4. Risk perception
5. Risk communication

Interview questions were prepared with respect to the aforementioned categories. In some cases, some overlap between core subjects exists. Relevant key topics are also presented to be traced by asking each question.

To clarify the concepts of core subjects and contribute to effectiveness and proper usage of them in risk education, the key topics were traced and discussed during the interviews. Hence, it will be possible to know how such concepts are explained to and discussed with students during performed practices.

Table 3.2. Interview Questions

Relevant core subjects and basic pillars categories	Interview Question	Key topics
The scientific basis of risk science	1. Please introduce yourself and explain about your experience regarding risk education.	The context of risk education, Involvement in Knowledge A type or B type
Fundamental concepts	2. How do you, if at all, introduce risk concept to students?	Risk concept Risk definition Matter of age and back-ground knowledge
Fundamental concepts	3. How do you, if at all, explain uncertainty concept regarding risk to student?	Uncertainty concept Uncertainty types Utilizing numeracy (probability) Utilizing qualitative methods
Fundamental concepts	4. How do you, if at all, explain variety of risk consequences for students?	Negative / Positive consequences Tradeoffs of various outcomes
Risk assessment Risk management	6. How do you, if at all, teach students to assess risk?	Cause and Consequence Analysis Qualitative / Quantitative measures Role of knowledge Utilizing the results to manage the risk

Table 3.3. Interview Questions-Continue

Relevant core subjects and basic pillars categories	Interview Question	Key topics
Risk Assessment Risk perception	7. How do students, if at all, learn to define risk acceptance criteria?	Acceptability and tolerability of the risk
Risk management	8. How do you, if at all, explain risk assessment and decision-making relationship to students?	Utilization of risk assessment results for decision making Diversity of perspectives in decision-making Limitations of risk assessment for decision making
Risk perception Risk communication	9. How do you, if at all, explain personal judgment and risk perception to students?	Risk perception Emotions and affects and personal judgements Distinction between personal and professional judgment The importance of cultural and socio-economic background
Risk perception Risk communication	10. How do you, if at all, explain importance of considering risk to students?	The importance of risk education for risk communication Personal and organizational protection Active role in personal and social life, Uncertainties in life and the World

The interview results were transcribed precisely, and the key themes were categorized. The results in addition to the data from participatory observations were analyzed with respect to key topics of each question. All collected data from performed interviews and participatory observations during the conference were then used to study the hypothesis with respect to risk science which will be thoroughly discussed in Chapter 5.

3.3. Limitation

One of the limitations is the matter of access to a limited number of experts and practitioners. The subject is emerging and hence there are a few numbers of practices, experts, and practitioners. Accordingly, twelve invitations were sent to the target groups. However, only seven of the invitations were accepted.

Due to the scarcity of data resources and limitations to access experts and practitioners for the interview, it is not possible to target a specific age group of students who are taught about risk and decision making. The studied practices presented in this study, target age groups from 11 to 18-year-old students.

Collected data are from different practices with different aims and contexts. Not all of the practices were intended to educate children and teenagers about risk. This can affect data collection since the underlying perspectives may not be focused on the risk education itself but on other purposes.

Chapter 4, Results

To fulfill the aim of this research and to find out how basic pillars of risk science are reflected in academic practices of risk education by semi open-ended interviews, 10 questions were asked from interviewees. In this chapter, relevant data will be presented.

The interviewees' responses and results are presented in three main groups; Canada (Group C), the Netherlands (Group N), and diverse countries group which are Norway, the United States, and Germany (Group D). The results will be presented for each question in the following paragraphs.

4.1. The Experts' Area of Expertise

Experts were asked to explain their experiences about performed practices of risk education since we wanted to know how they got involved with risk education, what their professional background is and in what context the practice has been performed. This could also make clear which disciplines are involved in producing knowledge A type for risk science.

Observations and Results show that the experts and practitioners are from various professional backgrounds such as teaching, risk analysis, HSE and decision making. Variety can be seen in the aim and context of performed risk education practices. Not all practices' purposes are to perform risk education and to educate children about risk but to enhance students' awareness in the contexts such as decision making, work safety, the sexual health of teenagers, and geography. Refer to Table 4.1 for a summary of discussed topics and context.

The target age group for risk education in group C was 11 to 12-year-old students. But in group N, students with a broader age range, from 11 to 13-year-old as well as teenagers in high schools, were the targets of the practices. Group D was focused on teenage students in high schools and vocational schools. However, in some cases in group D, the purpose of the practices was not risk education but to perform research in fields in which the risk concept plays an important role. For example, in Norway, the focus was to study the benefits of risky play for children. As mentioned before, the data gathered from this group is for more examination of the risk concept in different contexts where children are involved.

Table 4.1. Context of Risk Education Practices, Experts' Professional Field and Students' Age Range

	Group C	Group N	Group D
Experts' Professional Area	Teaching Decision making	Teaching Risk analysis Geography teaching	Risk assessment and HSE Decision making Children's physical play (risky play)
Context of risk Education	Real life issues (e.g. climate change) Life examples ongoing around students	Risk education Real life issues Geography	Work hazards and safety Sexual health Plays
Students' Age Range	11-12-year-old students	11 and 13-year-old students Teenagers (High school students)	Teenagers (High school and Vocational school students) 1-6-year-old children

4.2. Introducing the Risk Concept to Students

Experts were asked how they introduce the risk concept to students. Accordingly, the main discussed key topics were the definition of the risk concept, the matter of background knowledge, and the appropriate age for understanding risk concept. Understanding these fundamental concepts can contribute to effective utilization and performance of risk education.

In group C, the risk concept was introduced as a necessary concept that can contribute to decision making. This can be inferred from the discussion in the conference about the ongoing practices in Canada and the response of practitioner 1:

It [Risk] is more involved in the decision part and realizing at making decision what the risk are when they students are having a decision about climate change or activity on a playground and what kinds of risk might be involved in that decision. Risk and values go together hand in hand.

In group C, the main purpose was improving students decision-making abilities. Consequently, knowing about the risk concept is one of the significant elements. The concept was introduced in the context of environmental issues such as climate change and students' values where their decisions can be effective. Therefore, they need to know about risk concept and uncertainty. The activities in the playground and classrooms have provided an effective basis to contextualize the concept and explaining it to the students.

In most of the practices of group N, the concept was introduced to contribute to the understanding of the risk itself and hence to balance the uncertain outcomes or mitigate the undesirable consequences. Practitioner 2 in group N explains that risk is explicitly introduced through three steps:

[To introduce risk] We teach them [students] three different elements: there is something that they value, for example, the future plan or health. It is something that certainly they care about it. Secondly, if they need to make a decision, it involves them to come in an active way. [And thirdly] This is under situations in which you are not sure what will be going on.

The statement explicitly clarifies that when risk is discussed, students consider something they value and that there are uncertain outcomes when they decide about that value. The definition also points out to risk and decision-making correspondence. However, in group N, other definitions of the concept can be seen. The concept has been introduced by focusing on its hazardous side or by providing a probabilistic definition. Accordingly, expert 2 with respect to flood-risk education mentions:

It is all about the chance [probability] of something that can go wrong (e.g. flooding) and the relevant consequences.

In group D, responses were diverse about the definition of risk. In some cases, risk was defined as the probability of occurrence of a hazard.

In this regard, expert 3 and practitioner 3, respectively mention:

[Risk is] understanding that there's a probability of the things that may happen and so understanding the probabilities is necessary to make decisions about what you are willing to accept, and then at the same time, you can mitigate your risk. I talk more about of hazard side of things.

[In industrial work environment] Risk is defined as the likelihood of occurrence of a hazard.

Such explanations of the risk focus on the hazardous and probabilistic side of the risk concept.

However, in this group risk was also introduced as something which can bring a positive opportunity for the students. Expert 4 explains risk as something that:

Could be interpreted as something that has negative consequences but also it has a lot of positive effects.

Table 4.2 shows the summary of results for this question.

Table 4.2. The Risk Definition Introduced to Students

Group C	Risk is more involved in decision making. Risk and values go together.
Group N	Risk is about values at stake and making decision about them under uncertain conditions. A specific definition of risk, probability times consequence, is used. The hazardous side of risk is introduced.
Group D	Risk is defined as the likelihood of occurrence of a hazard. Risk is about a probabilistic nature of the things that may happens where decision making is needed for accepting or mitigating it. Risk and hazard are two different things. Risk can have positive effects.

Another discussed topic was the matter of age and background knowledge of students. Overall, the experts and practitioners state that students' age, which indeed influences the strength of their background knowledge and cognitive abilities, plays an important role in the understanding of the discussed topics. In this regard, one of the experts mentions that a lot of 11 to 12-year-old students do not understand the concept of risk. However, as they start to be cognitively aware and their brain starts development, this is a good age to develop their understanding of the risk concept and continue relevant activities. In Table 4.3, the reasons for selecting the specific age for risk education are summarized.

Table 4.3. The Reasons Behind Selecting the Specific Age Groups for Risk Education Practices

Group C	This rage range (11-12-year old students) is chosen because they start to be cognitively aware and their brain starts developing.
Group N	11 and 13-year-olds were chosen because research indicates that younger children would not be able to handle the mathematical abstractions. This age has been chosen, because in the Netherlands for all students until 15-year-old, geography is compulsory course.
Group D	Teenagers tend to take more risks and they are also in situations that tend to be much riskier situations than most adults find themselves in. Children tend to do risky plays

4.3. Explaining the Uncertainty Concept to Students

As one of the main concerns of this research, experts were asked about their method of explaining the concept of uncertainty. Accordingly, key topics discussed in this question were the uncertainty concept and the methods utilized, such as qualitative and quantitative methods,

real-life examples, and games. This is asked as the concept was one of the main elements in defining risk.

In group C, a distinct conceptualization about the uncertainty cannot be seen among the responses. However, with respect to participatory observations and respondents' explanations, the concept is introduced as when something is unknown, or one cannot be sure about its occurrence. To introduce the uncertainty concept, both qualitative and quantitative methods have been used through games and real-life examples. These are introduced as effective tools since 11 to 12-year-olds do not have an understanding of the uncertainty concept. Therefore, generating real-life scenarios, such as the events happening at playground, is more comprehensible for them. In addition, other tools such as dices, spinners, and colors are used for introducing the uncertainty concept.

In group N, the uncertainty concept has been introduced not only by means of playing tools but also by using personal and general real-life examples. The concept was explained in two steps by various qualitative and quantitative methods. At first, the students became aware of limited scenarios under uncertain conditions. Practitioner 2 explained:

First, we do this [introduce the uncertainty] with the dice. On a die, there are only 6 sides. Then we let the students' practice. Then we ask is there a possibility that you throw a 7? They say no because there is no 7 on the dice. Is there a possibility of throwing a 0? No, you can't. So, they basically have all the information which can possibly happen. The only thing is that they don't know what will happen. [To know this] Then we let them exercise, and we tell them it is a fair dice and throwing the dice many times, you let them know and see that when you throw it you get a kind of distribution and also they do it with a loaded dice and after several times throwing they see a specific distribution. They understand this very well.

Next, students were involved with games like basketball where scenarios are unlimited, for making a basket. Accordingly, practitioner 2 continued:

The second part, by playing basketball, I ask students can you please explain to me all the possible scenarios with playing basketball. They sort of puzzled because they want to tell you, but they cannot. [They are asked] Why not? Because there are so many things we don't know, they say. And they mention there are lots of things that can affect the scenarios in this case.

In the latter explanation, which introduces unlimited scenarios, the purpose has been explaining the uncertainty concept in real life context where various factors can affect the uncertainty of outcomes.

The responses of group D indicate that the uncertainty concept is not discussed clearly since it is not a matter of concern in the performed practices.

Refer to Table 4.4 for the summary of the results.

Table 4.4. Uncertainty Definition and Methods Used for Introducing the Concept

	Group C	Group N	Group D
Concept introduction	Explaining and contextualizing the concept by games, through real life issues or in the environmental context	Explaining and contextualizing the concept by games, through real life issues or in the environmental context Explaining two types of uncertainty: with limited scenarios and with unlimited scenarios	Not at all or no explicit discussion about the concept
Utilized methods	Playing tools Using real life examples Generating scenarios	Playing tools Using personal and general real-life examples Generating scenarios	No specific tool

4.4. Explaining the Risk Consequences to Students

Next, experts were asked how they explain introducing risk consequences to students. The main key topics discussed were introducing both positive and negative uncertain outcomes and balance these outcomes. The question aim was to examine whether the risk consequences are introduced only negatively, or their positive aspects are also being explained.

In group C, by generating scenarios, students were getting familiar with various consequences either positive or negative. The practitioners believe that generating scenarios provides practical opportunities for students to understand a variety of consequences.

In group N, for some practices both positive and negative consequences were discussed. As an example, practitioner 2 mentioned:

[To make students able to do tradeoffs for consequences] We let them jot down the different elements they would like to incorporate in their spatial planning site. There are houses, schools, different places we go. Then we talk about risk, and the data about city and also how to mitigate the risks. Then they do the design, using the ideas they have developed in the past lessons. Then questions are there: for example, there is a factory produces hazardous substances. It needs to be relocated. They do the tradeoffs between benefits and costs of the relocation. For example, if my father is going to factory every morning, he will be stuck in traffic. So again, they need to do the tradeoff. The benefit is relocating the factory not to have the high school affected. But my father will be in traffic every morning and that is a cost.

Students learn to consider tradeoff between various outcomes. However, other perspectives toward the consequences of risk exist in this group. For instance, in flood-risk education, only negative and hazardous outcomes are a matter of interest.

Accordingly, expert 2 mentioned:

It is all about the chance [probability] of something that can go wrong [e.g. flooding] and the relevant consequences.

Most of the responses in group D showed that during the practices, negative consequences were more focused on, with an exception of researches on risky play for children, where both positive and negative consequences were considered.

Discussed topics are summarized in Table 4.5.

Table 4.5. Introducing Variety of Consequences to Students

Group C	Through generating scenarios for real life situations Focusing on both positive and negative outcomes Performance of tradeoffs between various consequences
Group N	Through generating scenarios for real life situation Focusing on both positive and negative outcomes Performance of tradeoffs between various consequences Focusing on hazardous and negative outcomes (in some cases)
Group D	Focusing on negative consequences and hazards (in most cases) Focusing on positive outcomes (in one case)

4.5. Introducing Chance or Probability Concept to Students

The purpose was to examine the meaning of the chance or probability concept in dealing with risk. The key discussed topics were the meaning of chance or probability and the probabilistic perspectives used to introduce the concept. To gain reliable results from the utilization of probability in risk education, it is important to have a strong understanding of the aforementioned concepts.

The responses of group C showed that chance and probability concepts are used to discuss the occurrence of a specific event or scenario. Explicit definitions of the concepts were not used since it is not easy for students to understand them given their young age. Real-life contexts, like the occurrence of natural disasters, were used to help students to understand and utilize such concepts. Moreover, both numbers and words were used to express the chance or probability of the occurrence of a scenario. To explain the concept to students, playing tools

such as dice, spinners, games, generating scenarios, and group discussions were used in classrooms as well.

In the practices of group N, the meaning of chance or probability was introduced explicitly. By asking questions such as how likely students think a risk is, they became familiar with the concepts. The practitioners were using playing tools, games, and group discussions. Following such activities, the concept was introduced as the likelihood of occurrence of an event which is uncertain. In another practice in group N, the concept was introduced as the frequency of an event. But the students were not deeply involved with discussions about the meaning of the chance or probability.

Finally, no explicit discussions about either the meaning of the probability or types of probabilistic perspectives exist. In this regard expert 3 mentions:

That’s a concept people having a really hard time understanding. But again, our goal is to try to get people to make better decisions, it’s not trying to make people understand uncertainty or probability. Many people don’t like thinking about numbers. It’s not going to be that meaningful for them.

Other reasons for not introducing the concepts mentioned were because they were not helpful for decision making, or they were not being relevant to the context.

Table 4.6 includes a summary of the mentioned results.

Table 4.6. Introducing Chance/Probability Concept to Students

Group C	Chance and probability terms are used in practices. The concept discusses the occurrence of a specific event. Both numbers and words are used to express the concept. Utilized methods: playing tools such as dice and spinners, games, generating scenarios, group discussions
Group N	The concept is discussed with students. The concept is introduced as the likelihood of occurrence of a specific scenario which is uncertain. In some cases, the concept is defined as the frequency of an event. Utilized methods: playing tools, games and discussion.
Group D	The concept is not discussed explicitly.

4.6. Introducing Risk Assessment to Students

We asked the experts and practitioners about explaining risk assessment to students. The key topics discussed in this question were cause and consequence analysis, types of measurements used to measure risk, and understanding the role of knowledge. Aforementioned topics were

discussed to see whether the core subjects, risk assessment, and management were reflected in the performed practices.

Regarding the participatory observations and the interview results, in performed practices of group C, both qualitative, e.g. matrix or ranking, and quantitative, e.g. probability, methods were used to introduce risk assessment for the generated scenarios. However, the process of risk assessment was not introduced clearly since it is mentioned that assessing and measuring risk is still a tough topic in the practices, mainly because the practitioner's knowledge about risk science, as well as students' knowledge, is limited.

During the group discussions and presentations of the conference, it was found that the focus of practices in Canada has been to improve students' decision-making abilities. In this regard practitioner 1 mentioned:

Measuring and assessing risk is a tough one. We need to explore a little bit more. We don't know enough about risk science to know how to assess and measure risk.

Despite risk assessment being discussed to some extent in this group, it is hard for students to utilize the results for treating the risk and making a decision. In addition, it was mentioned that in some cases providing extra knowledge to students about an uncertain scenario results in changing their assessment outcomes.

With the same approach in group N, assessing risk was introduced partly qualitatively and quantitatively to students. Moreover, it was mentioned that generating scenarios about real life issues is helpful for students to learn about risk assessment. In addition, it was discussed with students that to interpret the situations, they always need more information due to the changing nature of the situations. As an example, they were reminded to always improve their knowledge for predicting uncertain outcomes in a basketball game.

In the practices of risk education in geography context in group N, it was mentioned that students were getting familiar with the causes and consequences of risk of flood. Expert 2 mentioned:

During these lessons, they first become aware of the causes and consequences. Then they have to make a plan of how to communicate flood risk and the consequences to the neighborhood.

The students also had the opportunity to measure the chance of the consequences, through a simulation program as part of the program. The program provided qualitative and quantitative methods for risk assessment. Probabilistic tools were used in the simulation program for measuring, but students did not confront directly with them.

Finally, in group D, risk assessment was not a matter of interest. Qualitative assessment was scarcely introduced to students. Accordingly, expert 3 mentioned:

Often, they [students] are not engaging the risk. They are engaging the behavior without making trade-off about the risk in their heads. People usually do not engage in such systematic risk analysis [assessment] in their daily lives.

Moreover, improving knowledge has been emphasized and introduced to students for improved decision making.

Refer to Table 4.7 for a summary of the mentioned discussions.

Table 4.7. Explaining Risk Assessment to Students

Group C	<p>Risk assessment is a tough topic for students and teachers.</p> <p>Assessing risk is not introduced clearly.</p> <p>Both qualitative and quantitative methods are used for assessing risk. (e.g. matrix, probability, etc.)</p> <p>Students can hardly use the results of risk assessment for treating the risk.</p> <p>Providing extra knowledge is helpful for students to find new solutions.</p>
Group N	<p>Assessing risk is introduced implicitly.</p> <p>Both qualitative and quantitative methods are used for assessing risk. (e.g. probability, simulation tool, etc.)</p> <p>The importance of knowledge improvement for the assessment is discussed.</p>
Group D	<p>Risk assessment it is not the matter of discussion.</p> <p>Qualitative methods are scarcely used.</p> <p>Knowledge improvement is introduced for improved decision making.</p>

4.7. Introducing Risk Acceptance Criteria

The question's purpose was to examine the students' awareness of risk acceptance criteria during the practices to understand whether they learn about the level of risk they accept and the way they define that level.

With respect to the participatory observations and the interview results of group C, this topic was not discussed clearly in the classroom. Although during the practices the students learned about the levels of their willingness to accept the risk, it took a lot of talking and time for them to understand such a concept.

In group N, this topic was not discussed with students. The topic has been discussed in risk education practices for adults but not for children and teenagers.

The results of group D showed that students were not aware of the risk acceptance criteria themselves. They were reminded to always ask themselves how safe is safe enough so that they become aware of the level of the risk they were willing to accept. However, responses also indicate that student's personal preferences could be affected by their peers, which puts

pressure on them to engage with a specific behavior without thinking about the level of the risk they are willing to accept.

Refer to Table 4.8 for a summary of the mentioned discussions.

Table 4.8. Introducing Risk Acceptance Criteria

Group C	The topic is not discussed explicitly in classrooms. Students become aware of their personal preferences and the level of risk they are willing to accept. Students become aware of peers' preferences.
Group N	The topic is not discussed with students clearly.
Group D	The topic is not discussed clearly with students. Students are reminded to always ask themselves how safe is safe enough to become aware of their personal preferences and level of risk they are willing to accept.

4.8. Explaining the Relationship Between Risk Assessment and Decision-Making

This question's purpose was to understand whether students are aware that assessing risks can provide the basis for risk management and decision making, and whether they know about the limitation of risk assessment. Moreover, it was a matter of interest to know whether students were familiar with the diversity of perspectives which can result in the diversity of decisions.

In group C, findings from the participatory observations and interview results showed the limitations of risk assessment and its relationship with decision making were not being discussed with students. Practices are about value-focused decision making based on the British Columbia redesigned curriculum. Additionally, students were learning about the diversity of perspectives in decision making. In this regard, practitioner 1 mentions:

Right now, in my school, we are really working with decisions and through decision-making, the risk becomes involved. I do not necessarily teach risk evaluation. I teach decision and the risk becomes around the decision that students are making.

Findings from group N showed that students were taught that risk and decision making always go together. Limitations of quantitative risk assessment have been discussed with students as well. In this regard, practitioner 2 mentioned:

During the discussions in the classroom, we explain that we can always give numbers [quantify] to our risk [assess the risk], but numbers do not give us how to decide about the risks. We need more information.

Students are also taught that their values may not be a value for others. In this regard, to become aware of diversity of perspective, as part of the flood-risk education in the Netherlands, students talked with their family and friends about their preparedness for a flood. In addition, they studied about government actions for managing flood risk to become familiar with the government's efforts and perspectives. Finally, the students learned about the limitations of risk assessment for decision making by emphasizing that using numbers and probabilities by themselves are not enough for decision making. They learned that they should always pay attention to the quality and source of the knowledge for decision making.

In group D, the relationship between risk assessment and decision making was not discussed with students. They were only taught that if a risky situation comes up, then they need to make a decision and pick one of the available choices. The limitations of quantitative risk assessment were not introduced to students either.

Table 4.9 shows a summary of mentioned discussions.

Table 4.9. Introducing Risk Assessment and Decision-Making Relationship

Group C	The relationship between risk assessment and decision making is not discussed. Limitations of risk assessment are not discussed. Students become aware of diversity of perspective in decision making.
Group N	It is discussed that for decision making it is necessary to evaluate the risk. The students learn that only using numbers and probabilities are not enough for decision making. Students learn to pay attention to the quality and source of the knowledge for decision making. It is discussed with the students that their values may not be a value for others.
Group D	The relationship between risk assessment and decision making is not discussed. Limitations of quantitative risk assessment are not discussed.

4.9. Explaining Personal Judgment and Risk Perception to Students

This question was asked to examine the reflection of the roles of personal judgment and risk perception in the practice. The purpose was to know whether students are learning about the effects of emotion, personal judgment, and risk perception in dealing with risk. Additionally, the experts and practitioners were asked to give their opinion about the role of the cultural and socio-economic background of students when it comes to judge a specific risk.

In group C, the students learned about different ways people judge risks through narratives, stories, literature, and conversations. Moreover, there were discussions about how sometimes students judge risks differently from the reality. For instance, practitioner 1 from Canada indicated:

I use a lot of children stories and we can talk about the decisions that the characters are making and the risks. We talk about how sometimes we think something is a risk as it doesn't have to be. I teach that through conversation and literature and kids' books.

Nevertheless, there were not any discussions about the effect of personal emotions and judgments on decision making.

In group N, even though the effect of personal judgment and emotions in dealing with risk have been discussed, in some cases risk perception did not received enough attention. In some cases, the experts and practitioners addressed the reflection of risk perception in the basis of the practices. For instance, expert 1 mentioned that personal judgment and risk perception are different from representing probabilities. Or as another example, expert 2 discussed the effects of knowledge on flood-risk perception of students. However, this could not be seen among all the practices in this group. Overall, despite discussing the effect of emotions on decision making, the importance of risk perception was not clarified explicitly. In this group, cultural and socio-economic backgrounds were named as influential items on personal judgment.

Finally, in performed practices of group D, it was discussed that long exposure to risky situation can affect students' risk perception. So, they learned to pay more attention to experts' judgment about risks in the practical environment. However, personal judgment and risk perception were not introduced to them.

Table 4.10 shows a summary of mentioned discussions.

Table 4.10. Explaining Personal Judgment and Risk Perception

Group C	The topic is not discussed explicitly with students. Cultural and socio-economic background are mentioned as influential items for risk perception and personal judgment.
Group N	The topic is not discussed explicitly with students. Only the effect of emotions in decision making are discussed. Cultural and socio-economic background are influential items for risk perception and personal judgment.
Group D	The topic is not discussed explicitly with students. Students learn that long exposure to risk situation can affect their judgement about a risk. Students learn to pay more attention to experts' judgement about risks in practical environment. Cultural and socio-economic background are influential items for risk perception and personal judgment.

4.10. Importance of Learning About Risk

The focus of the last question was on the importance of risk education. The question's purpose was to investigate whether students become aware of the importance of risk education as one of the most important functions of risk communication. Risk education can be helpful to enhance students' competency to have an active role in risk communication and hence in solving real-life problems.

In group C, with respect to the participatory observations and the interview results, it was revealed that students became aware that they should know about risk since the world is becoming more uncertain especially when they get around environmental risks. Hence, it is important to understand what the uncertainties and risks are. Then a better decision can be made based on a better understanding of uncertainties and risks.

In group N, responses indicated that risk has been introduced as a tool that can contribute to the separation of knowns from unknowns. Therefore, it is helpful to develop students' knowledge about what they want and what is likely to happen. They became aware that being educated about risk can help them to have an active role in their personal and social life and improve their decision-making abilities.

The responses of group D revealed that students were explained about the importance of learning about risk since it can improve their physical and mental safety by lowering either their concerns or their physical injuries and the costs of their decisions. Moreover, it prepares them for their future.

Table 4.11 shows a summary of mentioned discussions.

Table 4.11. Introducing Importance of Learning About Risk

Group C	It is important to understand uncertainties and risks for better decision making.
Group N	Learning about risk can contribute to having an active role in personal and social life and improve decision-making abilities.
Group D	Learning about risk can improve students' physical and mental safety.

Chapter 5, Discussion

5.1. Fundamental Concepts of Risk Science

5.1.1. The Notion of Risk

To understand the notion of risk, it is important to understand that risk has two main dimensions; the uncertainty of the events or consequences of activities, and their severity (Aven & Renn, 2010). As previously discussed in section 2.1.3, the uncertainty dimension alone cannot be enough for judgment of a risk.

In the Netherlands, risk introduced to students addresses the uncertainty dimension about the values at stake, but not the severity dimension. That decreases the chance of students to understand the notion of risk properly. For instance, if two students bet on the outcome of rolling a dice, to judge who the winner is, they need to know the severity of the outcome in addition to the uncertainty. The severity can be the amount of money being bet for a specific uncertain outcome. Aven explains that severity “refers to intensity, size, extension, and so on, and is with respect to something that humans value (lives, the environment, money, etc.). Losses and gains, for example, expressed by money or the number of fatalities, are ways of defining the severity of the consequences” (Aven, 2015, p. 17). Therefore, the severity dimension plays an important role in judging risk.

In Canada on the other hand, the notion of risk is discussed through a decision-making process. Although the definition introduces values with respect to the risk notion, it is inconsistent with the broad definition of risk provided in section 2.1.3. The notion of risk is not defined and introduced clearly. It should be explained that the risk concept has the aforementioned two main dimensions. Moreover, only the probabilistic side of risk has been emphasized. Using this approach can be due to the fact that the Canadian practitioners had a background in decision making. During the conference, such a perspective was showing itself in group discussions and presentations by discussing decision making under uncertain conditions. More emphasis was on the decision making rather than the risk concept. Therefore, the unclear explanation of the risk concept can be due to practitioners’ limited knowledge about risk science. In this regard, when interviewees were invited from Canada to contribute to this study, most of them mentioned their knowledge does not fit risk science very well. In addition, the supportive curriculum of the practices in Canada may not be providing a clear definition of the risk concept. For that reason, it is important to examine a curriculum’s aim and content as well.

In some cases, in the third studied group, the uncertainty dimension has been replaced by chance or probability, which is not in compliance with the risk definition. The concept of uncertainty should be seen beyond probability (Aven, 2015). This could be because of the limited perspective of the experts and practitioners toward risk within the context of the performed practices. Probability is just one of the tools to express uncertainty and it is based

on the assumptions and knowledge which cannot be objective. For instance, teenage students may learn to use probabilistic tools to express the uncertainty of the outcome of a decision about their sexual health. However, their knowledge may be biased and affects their probabilistic perspective. In result, their interpretation of the situation may be influenced, and their attention may be restricted to some limited values at stake and neglect some other values.

5.1.2. The Notions of Uncertainty and Probability

The concept of uncertainty is one of the main features in defining risk. In this context uncertainty usually means the combination of both types of uncertainty; aleatory uncertainty and epistemic uncertainty (Aven & Renn, 2010). Considering the results contrary to practices in Canada and other countries, most of the practices in the Netherlands explain both types of uncertainty. When students roll a dice many times to get familiar with limited scenarios and the distribution of outcomes, they are becoming aware of the aleatory uncertainty. On the other hand, engaging students with games like basketball underpins introducing epistemic uncertainty, where students learn about unlimited number of scenarios that can be generated for a specific activity, for example the number of times they can throw the ball through the basket.

The uncertainty concept in Canada as well as in the third group either has not been clarified or neglected completely. Neglecting the concept of uncertainty and its types would not be possible to have a proper understanding of risk. Introducing the uncertainty concept plays a key role for analyzing the alternatives and decision making. Moreover, recognition of the type of uncertainty can affect assessors' choice of the measurement tool, whether a probabilistic or a qualitative tool. Unclear explanations about uncertainty can also be confusing and aimless for making a decision between various alternatives. As practitioner 1 explains, in practices in Canada the concept is introduced by consequences that could happen. This raises a concern that how uncertain a specific outcome could be or whether it is possible to characterize it by repeating an experiment (i.e. aleatory uncertainty). Moreover, questions arise on whether repeating experiments are enough for identifying uncertainty or whether more knowledge is needed for that purpose (i.e. epistemic uncertainty).

To measure both types of uncertainty of an event in the context of risk analysis, probability is the most common tool. Two interpretations exist for the concept of probability in this context. One is the frequentist probability, which is interpreted as "relative fraction of times the events occur if the situation analyzed were hypothetically repeated an infinite number of times" (Aven & Renn, 2010, pp. 76-77). When observable samples are limited or are not accessible, frequentist probability is not useful. Bayesian probability can compensate this shortcoming by incorporating all historical data, physical models, and expert's judgements (Paté-Cornell, 1996). Therefore, Bayesian probability can be one of the tools for expressing epistemic uncertainty, in which the relative frequentist probability is considered as chance (Aven & Renn, 2010).

The used methods in practices of the Netherlands address the two mentioned interpretations of probability. Practitioners try to make students familiar with subjective probability concepts by emphasizing on the role of knowledge in assigning the probability to an uncertain outcome. Although the interpretations are not explained explicitly and students are not engaged directly with probabilistic calculations, the utilized procedure can pave the road to improve students' cognitive ability about epistemic uncertainty. As an example, with respect to flood risk in the Netherlands, students should understand that to measure uncertainty of occurrence of flood, it is not possible to use frequentist probability since there is no access to infinite large population of recurring experiments. Hence, subjective probability must be used. Students can become aware that their knowledge plays a significant role in expressing the uncertainty of an outcome. If their background knowledge about flood risk is inadequate, the subjective probability they may assign for relevant uncertainties cannot be reliable. This is confirmed by a study by Bosschaart et al., where subjective probability was considered as an indicator of risk perception (Bosschaart, Kuiper, van der Schee, & Schoonenboom, 2013). In such cases using qualitative methods for expressing the uncertainty can be helpful as well.

Although the uncertainty concept is not defined and explained through clear procedures for students in Canada, a strong point in the practices is the utilization of various games and methods for expressing the uncertainty, not only quantitatively but also qualitatively. Some of them are scenario generating in real life context, rankings, and use of matrices. These methods improve the students' perspective toward seeing uncertainty beyond probability. Uncertainties should be seen beyond probability (Aven, 2015). Subjective probability cannot address hidden uncertainties which may turn into surprises (Aven, 2010). Even though the subjective probability takes all historical data, observed information, and assessor's knowledge into account, the strength of background knowledge affects the assigned probability. In case of a poor background knowledge, using qualitative measures of uncertainty can be helpful.

In most practices, the probability perspectives are not discussed or even reflected as thorough as they should be. Such an unawareness may lead to neglecting subjectivity of probability and the importance of background knowledge. A subjective probability with poor background knowledge, can hide uncertainties rather than unveil them. In this regard, not only students but also the practitioners and experts should improve their knowledge about the probability perspectives. It is also important to emphasize the role of background knowledge. Poor knowledge cannot unveil uncertainties and it may result in improper judgment of risk. As an example, age is an important factor. It is essential to consider students' age groups and their cognitive ability to comprehend the uncertainty and probability concepts (Greer, 2001). Different age groups require different curriculum for risk education. Comprehending probability does not seem to be a difficulty for students only. Adults also have trouble understanding probability as well (Gerd Gigerenzer, Hertwig, Van Den Broek, Fasolo, & Katsikopoulos, 2005).

5.1.3. Balancing Between Consequences

An important aspect of risk definition is to take both desirable and undesirable consequences into account. One strength of the performed practices of risk education in the Netherlands and Canada is that students are engaged with analyzing both desirable and undesirable outcomes through generating scenarios of real-life situations. They learn not only to avoid uncertain outcomes but also to make balance and do tradeoffs between both desirable and undesirable outcomes to get the highest benefit and lowest cost. Moreover, it will positively influence on students' reluctance toward the risk concept, which may make them risk averse and prevent them from developing opportunities.

Focusing only on negative outcomes of the risk may prevent students from developing their potential physical and mental abilities. As an example, only addressing probable injuries of playing in a playground can keep students from reaching their highest potential. Experiencing risk of playing, children develop their risk competencies and learn cognitive skills to reflect the right reactions when it is needed (Hansen Sandseter, 2007). As an example, with respect to flood risk education, where only hazardous consequences are considered, people think more about the expected loss from occurrence of flood. Such a conceptualization does not reflect desirable outcomes of flood, which could be deploying a huge amount of water for agricultural and urban use.

The reason behind focusing on the negative outcomes of the risk can be the conceptualization of the risk concept with respect to the teaching context. The context in which the risks are experienced affects the way people perceive them (Aven & Renn, 2010). When students are taught about risk in a work environment, expected loss and injuries due to occurrence of hazards are focused. As discussed earlier, such an explanation does not provide a broad definition of risk, but just a narrow perspective toward that. This also may result in having a risk averse perspective which may even lead students toward not performing the activities since they may lose the things that they value. Risk should be defined by focusing on both sides; avoiding losses due to undesirable outcomes as well as developing opportunities. For this purpose, both positive and negative consequences should be considered, and tradeoffs should be done to gain benefits.

5.1.4. Summary

In a nutshell, the fundamental concepts of risk science have been reflected partly in the studied practices. In this regard, practices of risk education in the Netherlands provide a more compliant definition of risk to students. This results in consideration of both desirable and undesirable outcomes of an event and hence, students find an opportunity to do tradeoffs to get the highest benefit while avoiding undesirable outcomes. Consequence analysis is an important step in risk analysis where it deals to a large extent with understanding of the phenomena (Aven, 2015). A better analysis of consequences provides more choices and scenarios and hence better decision making.

A good understanding of the fundamental concepts of the risk or uncertainty concept is sometimes difficult for students. Therefore, students' cognitive abilities and age with respect become important. Despite choosing the specific age groups with respect to their appropriate cognitive abilities and brain development, students in Canada face more difficulty to understand the fundamental concepts, while similar age groups in the Netherlands show a better understanding of the same concepts. One justification can be that in the Netherlands, utilized methods and procedures in the performed practices are more compliant with the risk concepts and consequently provide a clearer explanation. Studying students' cognitive abilities for understanding the risk concept with respect to their age is recommended as a research topic in risk education. Cooperation of experts from risk science and other disciplines can be helpful to design appropriate methods for introducing fundamental concepts to students with different ages. Risk science can provide knowledge B type to contribute to experts of other fields for producing knowledge A type with respect to the needs of risk education.

In addition, proficiency of teachers and curriculum designers about risk science is important. In some cases, in the examined groups the practitioners and experts mentioned that their knowledge about risk science is limited or not relevant. This results in presenting a less compliant definition of risk and hence ineffective practices. A study by Beyth-Marom confirmed that teachers themselves have difficulties in comprehending the curriculum topics and therefore, to improve their knowledge, they need practice as well (Beyth-Marom & Dekel, 1983).

It is important to recall that the aim is not to involve students with overwhelming probabilistic discussions, but to reflect fundamental concepts of risk science in risk education. Rather, the purpose is to engage students with methods and procedures which can improve their understanding and abilities in decision making under uncertain conditions. A good example of such a practice is an Elementary Approach to Thinking Under Uncertainty by Beyth-Marom, which contribute to improvement of students' probabilistic thinking skills by avoiding complex mathematical calculations (Beyth-Marom et al., 1985).

5.2. Risk Assessment

A comprehensive understanding of the fundamental concepts can improve students' abilities to assess risk. As previously discussed, risk can be described as a combination of specific uncertain consequences of an activity, and the strength of the relevant background knowledge to judge that uncertainty (Aven, 2016; Society for Risk Analysis, 2018b). By describing risk, the severity of the risk can be identified as well. In contrary, describing risk as the product of probability and consequences provides a narrow risk picture. However, risk description indicates that risk is broader than being defined as probability times consequences (Aven & Michiels Van Kessenich, 2019). Risk assessment is needed for a thorough description of risk. It is defined as a systematic approach for determining the nature and extent of the risk, which includes three main steps:

- Identification of relevant threats and opportunities
- Cause and consequence analysis
- Risk description (Aven & Renn, 2010)

Risk assessment is partly discussed with students in the practices of risk education in both Canada and the Netherlands, despite not being called risk assessment. Using terms such as evaluating consequence or measuring likelihood of scenarios confirms implicit discussions about risk assessment in classrooms. However, it is not explained systematically. The reason can be due to the fact that although risk assessment is introduced and explained to students, the knowledge of practitioners and experts regarding risk assessment is limited. Findings from group discussions in the conference as well as the interviews show that risk assessment is a tough topic for teachers as well, since their knowledge is not enough about risk science.

Shortcomings of risk assessment should be reflected in practices of risk education. In the practices of Canada, the students are engaged with using a simple risk matrix for having broad understanding of risk description. Risk matrix should be used with care since it has some limitations (Aven, 2015). For example, the strength of background knowledge, on which the probability of uncertain consequences assigned and used in risk matrix, should always be examined. Moreover, risk matrix cannot reveal information about the extent of acceptable risk. The strength of these practices is that students are explained and motivated to acquire knowledge for better risk assessment. As another example in the Netherlands shows, despite a proper way of presenting fundamental concepts of risk to students, the process of assessing risk is still vague and can be improved. The three step procedure of risk assessment can explain risk assessment more thoroughly

Among the experts and practitioners, some believe that using systematic risk assessment in real life situations should not be the aim. This perspective can be seen in the third group mostly. This is because the context of studies is about decision making where people are engaged in specific behaviors without performing tradeoffs for those behaviors. It is reminded that the aim is not to involve risk education with complex analytical risk assessment, but simply to explain how to use the learnt basic concepts for getting a result for decision making.

The goal is to help students to become able to identify a threat or an opportunity, its causes, its uncertain consequences, and further to measure those consequences. Hence, they can have a broad understanding of the choices and outcomes for controlling them. This directly improves their decision making. In the context of decision making, students are confronted with various choices which bring various outcomes where not all of them are avoidable (Aven & Michiels Van Kessenich, 2019). Risk assessment can improve individuals' abilities for controlling such situations either by avoiding losses or by developing opportunities. The author of the present study believes that to find the ability to identify hazards and opportunities, risk education should provide such a mindset to students. The three main steps of risk assessment must be evaluated more thoroughly.

Identification of Relevant Threats and Opportunities (Aven, 2015): As a first step, in every risk assessment, it is important to identify threats and opportunities of a specific risk. How

performed practices of risk education consider such outcomes has been discussed thoroughly in section 5.1.1. Assuming that the focus is on negative outcomes, it is important to identify hazards and threats since inadequate knowledge about them can prepare students for effective reactions. For example, identification of hazards in a playground, such as an ankle or wrist sprain and a broken nose, prepare students to show appropriate reactions when they face them.

Cause and Consequence Analysis (Aven, 2015): For each identified source of threat, it is necessary to examine the causes and consequences. Such analysis results in generating various scenarios about a specific risk. The more the students know about different scenarios, the more control they have. Moreover, such an analysis can be helpful to cover more scenarios and to avoid neglecting some. Useful graphical methods exist for presenting cause and consequence analysis such as the bow-tie diagram or the decision tree. The author believes that particularly such illustration can be helpful for students. For instance, the decision tree method has been used in a study to teach students about decision making (Abbas et al., 2004).

An example of a bow-tie diagram, in Figure 5.1, illustrates the causes and consequences of an initiating event. In this example the initiating event is addiction to marijuana. This topic is chosen since it is controversial among teenagers, families, and at schools. Mentioned causes and consequences are used from the US National Institute on Drug Abuse for Teens (NIDA, 2019).

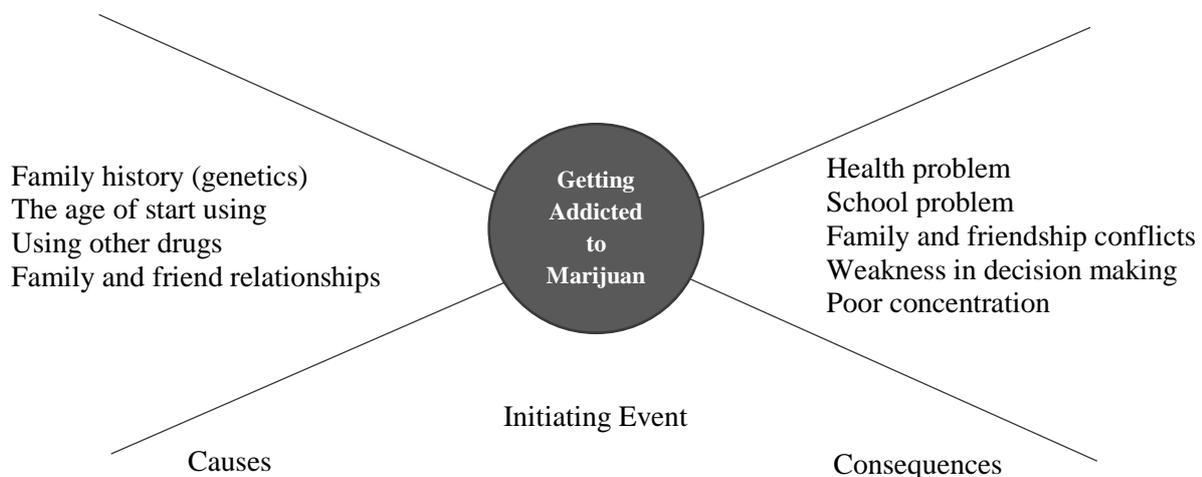


Figure 5.1. An Example of a Bow-Tie Diagram

By using such a diagram, various scenarios can be generated and then probability can be used for measuring uncertainty of each scenario. It can always be asked how likely a specific scenario is to occur. However, probabilistic risk description cannot be sufficiently informative as the strength of background knowledge is a matter of concern (Aven, 2015). This topic has been previously discussed in section 5.1.2.

Risk Description (Aven, 2015): Finally, by considering the previous steps risk can be described. One way of describing risk is by using a risk picture. A broad risk picture can be helpful for:

- Predicting the quantities of the interest (for example costs, numbers, etc.)
- Knowing the strength of background knowledge
- Knowing the factors which are manageable

However, it is important to remember that even the risk picture is conditional based on the background knowledge since it is formed with respect to the subjective probability. Therefore, it is always important to pay attention to the strength of background knowledge.

5.2.1. Summary

In summary, risk assessment as one of the main pillars of risk science can be a useful method of identifying hazards as well as opportunities, describing their consequences, and exploring their intensities. It is a scientific and useful tool for getting broad knowledge about possible events and their consequences (Aven & Renn, 2010). However, this pillar has been reflected partly in performed practices of risk education. For teaching risk to students, such a tool is helpful to broaden their perspective on risk and uncertain outcomes. The aim is not involving students with a complex analytical systematic risk assessment but simply to improve their ability for gaining broad knowledge of risk. Such a process should be adapted with respect to the degree of risk complexity, uncertainty, and ambiguity (Renn, 2008). In addition, students' age group must be reflected. It should always be emphasized that the strength of background knowledge plays a vital role in assessing risk. Adaptation of the risk assessment process for risk education is generating knowledge A type which needs utilization of knowledge B type as well as cooperation of experts, both from the risk field and other fields.

5.3. Risk Management

Risk management is referred to as the conducted activities, measures, and judgments to manage risk by means of gained results from risk assessment and in a broader perspective risk appraisal. Risk management is necessary in order to make decisions appropriately and to avoid losses as well as exploring opportunities (Aven, 2018; Renn, 2008). In this regard, it is necessary to cover some basic points about risk management (Aven, 2018; SRA, 2018):

- Risk management should be distinguished from risk assessment
- Risk management decides the acceptance or tolerance of risk based on risk appraisal. Risk appraisal is traditional risk assessment in combination with assessment of concerns such as risk perception and social concerns. Risk acceptance criteria should be considered.
- Risk perception and emotions influence risk management

- Different strategies can be used for risk management such as cautionary or precautionary strategies

5.3.1. Distinguishing Between Risk Assessment and Risk Management

The aim of risk management is to decide about relevant measurements to mitigate or alter the consequences of risk. This is done based on the outcomes of risk assessment. Risk assessment as a tool provides basic information for risk management. It is very important to differentiate between these two perspectives.

Contrary to the practices in the Netherlands, the practices neither in Canada nor in the other countries reflect risk management explicitly in their discussions. This is inferred from the group discussions in the conference and the practitioners' responses when they were asked about their opinion on how the outcomes of risk assessment are used for decision making. Limitations of risk assessment should be considered although it provides useful information for decision making. Accordingly, quantitative risk assessment is based on subjective knowledge which may either be weak or strong. Risk assessment does not and cannot prescribe a correct answer for decision making (Aven, 2018). This is where risk management as one of the main pillars of risk science plays a significant role.

The question may arise of why students need to be able to differentiate between risk assessment and risk management. The author believes that whether risk education's aim is to educate students to have an active role in their society, they should be able to recognize that risk management and risk assessment are different. Although they may not need to have a broad managerial and judgmental perspective for decision making, such an ability can be helpful for them in two ways. First, they become aware of the limitations of quantitative risk assessment. That is how their knowledge is subjective, inadequate, or limited in performing quantitative risk assessment, or being biased towards an issue. Second, they gradually become aware of the reasons behind the difference between their individual perspective and the decision maker's perspective. They can understand that for managing risk and decision making, it is necessary to see beyond numbers and quantitative measurements.

5.3.2. Acceptability and Tolerability for Risk

One of the main concerns of risk management is interpreting the risk assessment outcomes to decide about tolerability and acceptability (Aven & Renn, 2010). These criteria, called risk acceptance criteria, cannot be derived from risk assessment alone. One reason is that risk assessment essentially is based on subjective knowledge, which might be limited. Moreover, a quantitative assessment of risk does not consider all concerns such as risk perception, social concerns, and socio-economic impacts. Risk assessment is only a tool to inform decision makers on how to manage risk. It is necessary to know to which level risk can be tolerated.

Risk acceptance criteria is scarcely and unclearly explained for students in the studied practices of risk education. The question arises that how students can be decisive when there is no reference for accepting or rejecting a choice. Having more information cannot help to make a choice about an uncertain outcome unless one has the knowledge on the extents of acceptable risk. Moreover, if the risk is unacceptable, it is necessary to know whether it is tolerable, and if not, how the undesirable outcomes can be reduced. None of these are possible unless there is a clearly defined reference. Such a reference will help students measure the magnitude of the alternatives and to decide on the best choice. It will also give them the knowledge on how to mitigate and manage relevant outcomes. In other words, the criteria can be helpful to know what can go wrong and what should be done if a certain threat occurs.

A risk is acceptable when the residual threats are low and consequently mitigating actions are not needed. However, a risk can be tolerable, which means that despite the existence of threats, mitigating actions can be used to reduce them. A risk can also be intolerable where even mitigating actions cannot reduce the threats. How to specify the borders between these three areas is debatable. The Traffic Light model is a useful tool for characterization of risk acceptance criteria (Aven & Renn, 2010). Refer to Figure 5.2.

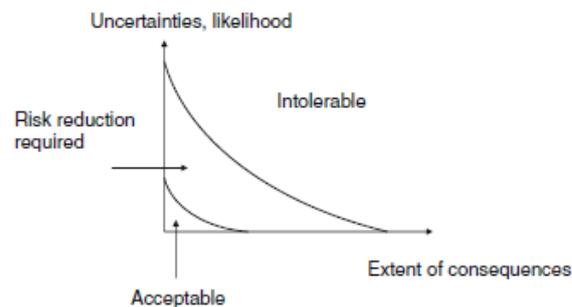


Figure 5.2. Acceptable, Tolerable and Intolerable Risks (Traffic Light Model) (Aven & Renn, 2010, p. 108)

Defining mentioned areas of acceptability of a risk is not easy. The criteria cannot be defined only based on risk assessment results, but other aspects such as social concerns should be considered as well. Renn states that evidence alone is not enough to derive the acceptability and tolerability of a risk by a society; rather, values should also be considered (Renn, 2008, p. 151). Making students aware of how this criterion can be defined is also helpful to show them how individual or societal preferences may result in acceptance of risk to different levels. Through such discussions, students can understand that when a risk is acceptable for someone it may not be acceptable for someone else, or when a risk is acceptable by an organization it may not be acceptable by the society. This topic is one of the motivations of the Netherlands government for educating students about risk (Michiels van Kessenich, 2017).

5.3.3. Considering Effect of Emotions and Risk Perception in Risk Education

For a proper risk management, evaluation of risk should be based on both evidence and values. Risk management can be successful when it is based on comprehensive risk evaluation. Hence, the effect of emotions, risk perception, and risk assessment must be considered (Renn, 2008). In the studied practices students learn about the effect of emotions and risk perception in different ways. Based on the participatory observations and the interview results, in the Netherlands students learn how their emotions may influence decisions. In the flood-risk education students become aware that their families and friends perceive the risk differently, which results in taking different actions. In Canada, students are explained about the level of the risk they may accept, or they discuss about their values and diversity of the values in decision making.

Despite the roles of emotions and risk perception are explained in the practices, risk education needs to clarify their effects more explicitly. Students need to become familiar on how tradeoffs between different alternatives can be affected by their emotions and perceptions. This topic will be discussed thoroughly in section 5.4.

5.3.4. Risk Management Strategies for Risk Education

All efforts in risk management are for performing tradeoffs between alternatives and to make the most appropriate decision. However, for an adequate risk management, cautionary and precautionary principles are helpful strategies (Aven, 2018). Utilization of these principles in risk education can be helpful.

Cautionary principle simply means to be cautious when a situation is uncertain by not taking an action, and it should be overriding when the situation is uncertain (Vinnem & Aven, 2007). This strategy can be very functional for students since it is applicable for any level of uncertainty. Students can learn that whenever there is a situation with an uncertain outcome, the first choice is to be cautious. It can also be introduced as a good starting point for assessing and evaluating the risk. For instance, when facing an email which asks for their bank account or password, they can be cautious.

Precautionary principle is a specific case of cautionary principle which explains that when there is a scientific uncertainty about an activity, the activity should not be carried out (Aven, 2015). Since scientific uncertainty can be discussed in different scales, such a strategy can be useful particularly for the students who are at the exposure of educational context. This can bring opportunities for them to learn more about managing uncertain outcomes and making reliable decisions.

5.3.5. Summary

In risk education it is necessary for students to become familiar with risk management' main aims and principles. They should become aware that quantitative results cannot be directly used for decision making since risk assessment is based on subjective quantification of uncertainties. For decision making, they need to do tradeoffs between various alternatives. They need a broader perspective to judge the strength of background knowledge. In addition, effects of emotion and risk perception should be considered. Practices of risk education have not yet focused enough on explaining the importance of risk management since there are scattered trends in explaining risk management for students.

As a reminder the aim of the author is not to involve students with complexity of risk, but to make them aware of limitations of risk assessment. Students need to be able to differentiate the risk assessor's perspective from the decision maker's perspective to improve their risk communication skills and hence have an active role in their society later on. Risk education needs to consider and thoroughly explain risk management as one the basic pillars of risk science.

5.4. Reflecting Risk Perception in Risk Education

Among basic pillars of risk science, risk perception corresponds to the psychological aspect of risk. Risk perception is a subjective judgement or appraisal of risk by people (Renn, 2008; Slovic, 1987). For decision making and in risk management, people do not primarily rely on quantitative risk assessment or knowledge, but their perception of risk affects their judgement of risk. Reliance of risk perception on personal judgement and emotions is due to the influence of heuristics, which are cognitive skills to conclude from quantitative and probabilistic information for judging uncertainty (Kahneman & Tversky, 1974). Heuristics help people to deal with uncertain situations more easily. Such a judgement may give more weight to insignificant factors of risk.

Despite the effects of emotions on decision making in a few of the practices that have been discussed, the importance of risk perception is not reflected properly mostly due to the fact that risk education is an emerging topic. Moreover, the knowledge of the experts and practitioners involved with the practices may be limited. To underpin risk education more effectively and to utilize risk perception for efficient decision making, the topic should be reflected broadly in the basics of the practices. Being aware of risk perception helps students to know about their personal judgement, their level of risk acceptance, and the way they define or react to risk. Understanding these aspects can address why and how individual, societal, and organizational preferences can result in different risk acceptance criteria. It will also clear out the distinction between personal and professional risk appraisal (Aven & Michiels Van Kessenich, 2019).

Another important aspect of risk perception is that in spite of the fact that the general population may lack scientific information and knowledge, their basic abilities in conceptualizing risk is

strong (Slovic,1987). Numbers and quantitative risk assessment are not enough for communicating uncertain outcomes of risk or decision making. Therefore, for a successful risk management and risk communication, it is necessary to pay attention to how people perceive risk. That is the reason why risk perception as one of the most important pillars of risk science should be reflected in risk education.

Sociological and anthropological studies have shown that cultural and social factors play an important role in people's risk perception (Slovic, 1987). From a Psychology perspective, risk perception is based on various factors such as personal experience, social communications, and cultural traditions (Pidgeon, 1998). Risk education should reflect these factors in its basis so that students become aware of all influential factors for decision making. The way a risk is perceived is engaged with people's emotions, judgments, attitudes, and beliefs. Risk perception is the reason for some of the conflicts between the general population and the experts' perspective towards risk (Sjöberg, Moen, & Rundmo, 2004).

Various psychological elements can be named as qualitative factors which affect the situation and the context in which risk manifests and is perceived. Among these, the main factors are voluntariness of risk, personal controllability, familiarity, knowledge about risk, dread of risk and cultural and social factors (Renn, 2008).

5.4.1. Voluntariness and Risk Perception

Studies indicate that when a risk is voluntary, it is perceived as less hazardous and dangerous by people, while when it is involuntary it is perceived more undesirably. People tend to accept voluntary risks 1000 times more than involuntary risks (Slovic, 1987; Starr, 1969). The main reason behind this can be people's will for making free choices. When individuals are free in decision making, they feel that whenever they want, they can stop the risk or choose another path that is more beneficial. Moreover, choosing risk voluntarily always lets people do tradeoffs and allows them to pick optimal alternatives among all the available choices.

5.4.2. Personal Controllability of Risk

Another influential factor of risk perception is controllability. Risks which seem to be more controllable by people, are perceived less hazardous (Slovic, Fischhoff, & Lichtenstein, 1982). That can be the reason for people's choice of traveling by car rather than flying with planes as they find driving cars more controllable, while the truth is that flying with plane is much safer than driving a car. Seemingly people feel powerless when they cannot have complete control of a situation.

The effect of controllability on risk perception should be taken into account in risk education. As an example, teenage students may find a risk, such as smoking marijuana, controllable and therefore perceive it as a less dangerous risk. The way they perceive risk of smoking marijuana not only can affect relevant risk appraisal and their decision making, but also may result in

conflicts between their perspective and adults' perspectives toward the risk of smoking marijuana.

5.4.3. Familiarity with Risk

Being exposed to any risk for a long period of time can result in perceiving it less threatening. People tend to get used to risk gradually after they identify it. They find the familiar risk less hazardous even though the nature of risk still remains the same (Slovic et al., 1982). High frequency hazardous accidents can be perceived less important by people when they are familiar with such accidents. In contrary, the occurrence of a small accident in unfamiliar situations can bring more panic. Reflection of familiarity elements in risk education can make students aware of how gradually their perspective toward a specific risk can change. For instance, speeding is one of the examples that teenagers usually believe they are familiar with both the risks and how to control it. However, the technical risk still remains.

5.4.4. Knowledge About Risk

Unknown risks are perceived more hazardous by people in comparison to known ones (Slovic et al., 1982). People accept known risks easier than unknown risks. Knowledge play a major role in risk perception. As discussed before, in flood-risk education in the Netherlands, one of the aims was to examine the role of knowledge on students' flood-risk perception (Bosschaart et al., 2013). The study confirms that the students perceive the flood risk as a controllable and less dreadful risk since their knowledge about the flood is weak. Gaining knowledge about a specific risk can help students to get familiar with it and hence their perspective toward the risk can change. This can positively influence their risk appraisal and decision making.

5.4.5. Dread of Risk

Risks which seem to be dreadful from people's perspective correspond highly with people's perception of risk. In such cases people want more mitigating rules and regulations (Slovic et al., 1982). Dreadful risks, such as GMO, BSE, Vaccination, are highly probable to be discussed by public media because they are controversial, and people want restricting regulations on them. In this regard, the role of media also becomes important which is among cultural and social influential factors of risk perception (Renn, 2008).

5.4.6. Social and Cultural Factors

Although psychological approaches toward risk perception point out the patterns by which people perceive risks, they cannot address the reasons behind those patterns or why those patterns are perceived in certain ways by different people (Renn, 2008). Cultural theory indicates that "individuals choose what to fear and how much to fear to support the way of their lives" (Wildavsky & Dake, 1990, p. 43). For that reason, social and cultural factors of risk perception become meaningful.

Reflecting the cultural and social factors in risk education can play an important role in students' risk appraisal and decision making. As the topic is emerging, there is not enough data to support this claim. However, all the experts and practitioners confirmed that socio-cultural background of students is a factor that has a direct influence on students' risk perception. For instance, it is confirmed that in the Netherlands students do not perceive the flood risk as a dreadful risk since it is believed that their protection against floods is guaranteed by the measurements their government has performed. Therefore, socio-cultural factors are needed to be considered to evaluate which and how risks are perceived, and how they can influence decision making.

Noticeably, cultural and social aspects of risk perception include various factors. one of the most important factors is the role of the media (Renn, 2008). The media' role in influencing people's risk perception in today's world is important. Children' exposure to various types of media, specifically social media can have significant effects on their risk perception and decision making. An effective risk education should be helpful to improve students risk perception with respect to the role of media. As discussed previously in section 2.3.2, a study by Kline confirms the positive influence of educating children about the effects of media on their physical safety (Kline, 2005).

5.4.7. An Example for Contribution of Risk Perception to Risk Education

To complete this discussion about psychological factors of risk perception, an example with respect to student needs will be discussed.

Using drugs is a controversial topic which involves various groups in society such as students, families, teachers, and authorized decision makers. Among them, marijuana is one of the most controversial drugs since authorities, scientists, and the general public have different perspectives toward its desirable and undesirable outcomes. Such controversies are even more diverse within different countries and cultures. For instance, in the United States, about 61% of Americans say the use of marijuana should be legalized (GEIGER, 2018). In Israel public is more concerned about the fact that marijuana is addictive and believe that smoking marijuana leads to higher risks for the society and hence legislation can play an important role in supporting its medical usage. In Norway, having the same concern, the public asks for less support for legalization of marijuana's medical usage to prevent its recreational usage (Sznitman & Bretteville-Jensen, 2015).

Decision making for regulating medical usage of drugs such as marijuana, or banning drugs, involves public, scientists, and authorities. Due to different marijuana risk perceptions, conflicts exist between these groups. In this regard, marijuana risk is perceived differently by teenagers and parents. For instance, many young people in Australia feel that authorities and families exaggerate the dangers of marijuana and get their facts wrong about its nature (Duff, 2003).

Aforementioned issues confirm that teenagers perceive marijuana smoking' risk less dreadful, more controllable, and more known. Moreover, social and cultural factors as well as the role of media, are influential on the way marijuana risk can be perceived.

5.4.8. Summary

In summary, risk perception should be given attention in the basis of risk education as it can combine people's intuition with quantitative risk assessment. It can contribute to students knowing about their personal judgements about a specific risk and understand how their level of acceptance of a risk may differ from others'. Therefore, psychological, social, and cultural aspects of risk perception should be reflected as fundamentals of risk education. Considering such topics in risk education can make students and children aware of why and how their risk perception may be different from the decision makers perception. Hence, students become prepared for an effective risk communication which helps them to have an active role in their society and life in the future. An effective risk education should help children and teenagers to have a broad and inclusive risk appraisal for proper decision making.

5.5. Risk Communication and Risk Education

So far, the role of various concepts and pillars of risk science have been discussed with respect to the needs of risk education. It is now helpful to discuss the importance of reflecting risk communication, as one of the most important pillars of risk science in risk education.

Communication is seen at the heart of the risk governance framework developed by International Risk Governance Council (IRGC) (Aven & Renn, 2010). The position of risk communication in this framework confirms its importance in relation to phases of the framework. In the political and social area, one of the challenges of decision makers is to communicate the probability perspectives and relevant decisions with the society whose perception toward probability and risk varies from either decision makers or scientists. Therefore, risk communicators need to overcome probabilistic reasoning challenges with both scientists and society (Breakwell, 2014). Hence, educating the public by communicating the risk is emphasized.

Regarding the participatory observations and the interview results, almost none of the practices mentioned that risk education can contribute to risk communication. In risk communication, important factors are the content of the communication, senders and receivers' understanding of the content, their understanding of each other, and the plausible transformation of the content within the communication process. Risk education must reflect principles of risk communication to enhance students' knowledge about the aforementioned factors since a failure in communication can result in misunderstanding the risk.

Having a proper understanding of the content and the sides of the communication contributes to improving children and teenagers' abilities to participate actively in the society aligned with

the aim of risk education. Only in that case can they face and deal with risk more appropriately. Moreover, they will be able to communicate efficiently with decision makers and scientists. This can also positively contribute to having an efficient legislation since decision makers can have a better understanding of the public concerns about risk. For a successful risk appraisal and risk management, effective risk communication is needed.

Risk communication can be a mutual learning process for both the society and the decision makers. To have a multi-purpose risk communication which can strengthen mutual communication and mutual involvement in decision making, both sides of the communication need to understand each other. Indeed, educating the society for better understanding of each of the aforementioned factors result in a strong risk communication. In addition, risk communication is a bridge between decision makers or experts, and the public. This is helpful to understand the risk well by transferring effective messages. Good practices in risk communication help all involved parties to make informed decisions under uncertain situations and to enhance mutual trust (Renn, 2008).

5.5.1. Summary

So far it has been discussed that risk literate people are able to participate actively in their social, cultural, political, and economic issues (G. Gigerenzer, 2011). Risk literacy goals can be achieved through learning and improving numeracy and probability skills and consequently people will be able to interpret the meaning of risk for better decision making. The aims of learning probability were introduced to improve risk communication, decision making, and critical thinking.

However, as discussed so far for an effective risk communication, probability and numeracy skills are not enough. This is clearly understandable as individuals' risk perception is also a factor. In fact, people's understanding of risk is not limited to probability skills, but the way they perceive, and judge risk is part and parcel. This was clearly pointed out in the conference about practices in Canada that although the students are aware of the quantitative assessment, it is hard for them to ignore their emotions and personal judgements in making decisions.

People's heuristics and patterns of risk perception influence their understanding of the content of risk communication as well as its effectiveness. Such intuitive judgement of risk by people, beyond how strong their probability skills are, brings more uncertainty and ambiguity to final effects of the communication message (Renn, 2008). Therefore, risk education should broaden its perspectives to not only to teach children and teenagers about probability skills for effective risk communication, but to make them aware of all aspects of risk appraisal with respect to risk communication.

As one of the main functions of risk communication, risk education should be able to improve students' critical thinking skills. As introduced previously, critical thinking skills help children to improve their abilities to distinguish automatic thinking from decision making (Gregory, 1991). To fulfill key elements of critical thinking, which are defining a decision perspective,

making choices under uncertainty, and thinking about consequences, risk education needs to reflect more than probability literacy. It should be able to practice principles of an effective risk communication with students to facilitate them with informed decision-making abilities.

The aim is not to teach students principles of risk communication, but to reflect risk communication on the basis of risk education in a way that the designed curriculum be able to improve children and teenagers' abilities in critical thinking and decision making. Noticeably, risk education should not be seen as a means to persuade society or to overload students with technical and confusing information, but instead as a media to improve their knowledge and create a common understanding of problems and decisions, aligned with the aim of risk communication (Renn, 2008).

Chapter 6, Conclusion and Recommendation

6.1. Conclusion

To conclude the present study and to discuss the study hypothesis, there are several findings with respect to the discussions and results:

1. The present study confirms that despite some fundamental concepts of risk science being introduced to students in performed practices of risk education, they are not introduced or reflected sufficiently in the basics of those practices.
2. Fundamental concepts of risk science have been reflected more thoroughly mostly in practices of the Netherlands. Although such clarification is helpful to systemize relevant knowledge to evaluate different alternatives, it provides a narrow perspective by neglecting some of the important basic pillars of risk science such as risk perception and risk communication.
3. Based on the findings in Canada, fundamental concepts of risk have not been defined and explained clearly. It can be due to the fact that practitioners in Canada are from decision making disciplines and they may not have relevant knowledge of risk science. On the contrary, more emphasis is on improving decision making abilities of students. Similar to the Netherlands, risk perception and risk communication, as two of the most important pillars of risk science have been neglected in practices of risk education in Canada.
4. In the group of other countries, i.e. Norway, the United States, and Germany, depending on the context of practices, various definitions for fundamental concepts of risk science are introduced and discussed with students. As a result, some pillars of risk science have been reflected, however not thoroughly, while some others have been neglected.
5. Risk science can contribute to risk education by providing clear and systematic definitions and descriptions of fundamental concepts of risk science. Most of the performed practices of risk education focus on the dark side of the risk and have underpinned their practices by introducing risk as hazard, which prevents children and teenagers from developing skills and gaining knowledge about risk and decision making. Reflecting fundamental concepts and pillars of risk science in the basics of risk education can contribute to a better understanding of risk. Hence, opportunities can be developed, and decision making can be improved. In addition, risk science can clarify limitations of quantitative risk assessment.
6. Risk perception and risk communication as two of the most important pillars of risk science should be reflected in practices of risk education. If the aim of risk education is to empower children as future decision makers to have an active role in their society, and to communicate effectively with decision makers, systematic risk analysis is not

enough. People need more than numbers and quantitative risk assessments for understanding the risks and uncertain outcomes of their choices. It is necessary to make children aware of risk perception and the effects of their emotion and personal judgment on risk appraisal. Such issues can be clarified by reflecting risk perception and risk communication principles and frameworks in risk education.

7. It is inferred that lack of unity and coherence in perspectives toward fundamental concepts and pillars of risk science result in a confusing and inefficient practice of risk education. Hence, it may become a scary topic in public's eyes. Moreover, since risk is a multidimensional topic, it is a matter of interest of various disciplines such as education, psychology, and decision making. This is where risk science can support risk education to produce knowledge A type by providing basic concepts, principles, and frameworks in cooperation with experts from other disciplines.
8. To have an effective risk education the target should not only be limited to students, but educators are important as well. As a matter of fact, in many cases teachers and practitioners, as the ones who transfer and explain the concepts, are not aware of the fundamental concepts and pillars of risk science. Consequently, the practice of risk education can be negatively affected due to improper communication.

6.2. Recommendation

1. To the best of the author's knowledge, performed practices of risk education lack a systematic perspective toward students' age. It is recommended to design and perform research about risk education with respect to specific cognitive abilities of children and teenagers in different age groups.
2. Risk education practices should not be provided only for students. Relevant practices are needed for teachers and practitioners as well. Teachers' understanding of the risk concept plays a key role. Providing relevant practices for educators are needed as well.
3. Risk education can be practiced with respect to principles of risk perception. For instance, for different kinds of hazards, with respect to children's age and cognitive abilities, different practices and curriculum can be designed and tested.
4. Providing a coherent framework for risk education can clarify the main principles of such education, which can effectively improve children's knowledge and abilities for appraisal and management of risk as well as decision making. Setting such a framework is recommended.
5. It is recommended to perform research to thoroughly understand the amount of time children and teenagers can retain the knowledge they gain from risk education practices.

6. It is recommended to study the effects of cultural, social, and contextual diversity in risk education in addition to the way children and teenagers respond to it.
7. Although risk education is to empower children and teenagers for optimal decision making and having an active role in their society, it is recommended to study whether it can fulfill the aims of decision making disciplines. Therefore, it is helpful to study the mutual relationship and contribution of risk education and the field of decision making.
8. Risk education is an emerging interdisciplinary topic, which needs cooperation of experts from various disciplines in addition to risk science. Due to the fact that the author of the present study is looking at the topic from a risk science perspective, it is recommended to perform such studies in cooperation with other disciplines.

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