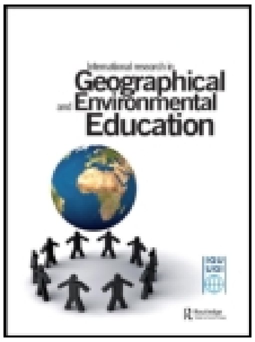

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Students' mental models with respect to flood risk in the Netherlands

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Until now various quantitative studies have shown that adults and students in the Netherlands have low flood risk perceptions. In this study we interviewed fifty 15-year-old students in two different flood prone areas. In order to find out how they think and reason about the risk of flooding, the mental model approach was used. Flood risk turned out to be not very salient and the mental models had a piecemeal character with fundamental misconceptions. Furthermore, the mental models consisted largely of descriptive concepts instead of concepts about underlying processes with respect to explaining and predicting flooding. Concepts with respect to hazard adjustments and disaster response were lacking most. Conclusions about how to use the results of this study in geography education were discussed.

Keywords: flood risk; mental models; 15-year-old students; geography education; the Netherlands

Introduction

For centuries, the Netherlands has faced the threats of the sea and of rivers. About 25% of the country lies below sea level and about two-thirds would be flooded frequently without flood defenses. Besides, part of the Netherlands belongs to the floodplains of the rivers Rhine and Meuse. Both the coastal plain and the floodplain are protected by dunes, dikes and dams. Over the last 1000 years catastrophic floods have taken place regularly. In the coastal plains, two major floods during the twentieth century were followed by huge projects to prevent the country from any further flooding.

Various studies (Bosschaart, Kuiper, van der Schee, & Schoonenboom, 2013; Terpstra, 2011) have shown that people in the Netherlands are hardly worried about flood hazards. Their trust in flood risk management is high, the likelihood of flooding is assessed as low, and few people tend to be prepared for possible flooding. It seems plausible to assume that these beliefs derive from the huge attention to the various water projects that have been accomplished during the twentieth century and from the idea that the national water authority in the Netherlands has taken care of all the safety measures in an excellent way. Heems and Kothuis (2012) call this "The safety myth of dry feet." The geography curriculum in primary and secondary education has also contributed to these beliefs. All students have been taught about the Delta Project in the south-western part of the Netherlands as well as the project around the Lake IJssel (Figure 1). To such an extent, the

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Figure 1. The location of Culemborg and Gouda in the Netherlands.

geography curriculum has mainly focused on safety measures without mentioning the consequences of a disastrous flood.

In recent years, the government policy with respect to flood risk has changed. Despite the high safety levels and the big efforts to prevent the country from flooding, the risk of flooding has remained. Therefore, the government has taken the initiative to prepare the inhabitants for possible flooding (Ministry of Transport, Public Works and Water Management, 2006). Among other things, this will involve raising peoples' awareness of the possible threat of flooding (Deltacommittee, 2008) in order to convince them it is extremely useful to be prepared.

In order to ensure that geography education could play an adequate role in raising flood risk awareness, it is necessary to examine the way students think about flood risk. Therefore, this study builds on the results of a quantitative study on the role of knowledge in the formation of 15-year-old students' flood risk perception in the Netherlands (Bosschaart et al., 2013). This previous study showed that students' level of knowledge about flood risk in their surroundings is low as well as students' flood risk perception. Furthermore, this study made clear that affective processes and cognitive processes play a role in students' flood risk perception. A positive relation between students' knowledge about flood risk in the surroundings and students' personal flood risk perception was determined. Because of the important role knowledge plays in flood risk perception and because knowledge in the previous study was measured with only a set of closed-ended questions, it is necessary to gain insight in what kind of knowledge students have and how they think and reason about flood risk. Therefore, this study has a qualitative character and focuses on the way 15-year-old students think about causes and effects of flooding as well as hazard adjustments and disaster response. For this purpose, we have interviewed 50 students in the Netherlands about flood risk, in order to determine flood risk salience, their mental representations of flood risk and the way they reason about it. The mental model approach (Morgan, Fischhoff, Bostrom, & Atman, 2002, Wood, Bostrom, Bridges, & Linkov, 2012a) was chosen because this method has previously been used and recommended with respect to risk communication research (Bostrom, Fischhoff, & Morgan, 1992; Kellens, Terpstra, & De Maeyer, 2012; Lave & Lave, 1991; Visschers, Meertens, Passchier, & de Vries, 2007). Furthermore, mental models' research has been applied to science education in order to explain human reasoning about physical systems (Collins & Gentner, 1987; Greca & Moreira, 2000) and geography education concerning physical geographical topics (Lane & Coutts, 2012; Reinfried, 2006; Reinfried, Aeschbacher, & Rottermann, 2012).

The 50 students that were interviewed came from two schools in Culemborg and Gouda (Figure 1). The two locations differ in elevation, flood mechanism, flood history and topographical situation. Culemborg lies in the floodplain of the river Lek and river Waal. These rivers are branches of the river Rhine. Both river branches are provided with dikes and all the people in this area are protected by these embankments. The area that is protected by dikes partly lies below the river level. During a period of high water, when the river forelands are filled, the water level of the river is 5 or 6 m above the land surface within the dikes. Although this area has a long history of flooding, there has not been any major flood event in the last 100 years. Nevertheless, during a period of extreme high water in 1995, 200,000 people had to be evacuated as a precaution but nothing happened.

Gouda lies below sea level and is approximately 30 km away from the sea. In the surroundings the lowest site of the Netherlands is located. Therefore, Gouda is threatened by the sea, directly and indirectly, and by the river Rhine. The river Hollandse IJssel, which flows past Gouda and has been blocked upstream, has the character of an estuary with tidal influences. During the last disastrous flood event in 1953, a storm at sea caused high water levels in the Hollandse IJssel and one of the dikes near Gouda burst. The devastating effects of this calamity could fortunately be remedied quickly. At the same time, many dikes elsewhere burst and caused more than 1800 deaths. Both Gouda and Culemborg are characteristic for, respectively, the coastal plain and the flood plain in the Netherlands.

Theory and expectations

Salience

According to Tversky and Kahneman (1974, 1981), salience influences the way people judge risks. Salience would influence the extent to which people perceive environmental hazards as a personal concern, and therefore it would provide an internal stimulus for action (Lindell & Perry, 2004). Because previous studies showed low flood risk perceptions among students in the Netherlands and because students never experienced a flood, we expect that the salience of flooding will be low.

Mental models

The foundation for the study of mental models was laid by Craik (1943) and was further developed by Johnson-Laird (1983). In general, mental models are characterized as incomplete representations of reality, which are unique to each individual, may consist of misconceptions and that are dynamic through time. According to Rapp (2005, p. 46) "mental models are internalized, organized knowledge structures that are used to solve problems." With respect to the knowledge structures, a distinction is made between declarative, structural and procedural knowledge. Jonassen, Beissner, and Yacci (1993) describe declarative knowledge as the awareness of objects, ideas or events, while structural knowledge is about the way concepts within a domain are interrelated. Procedural knowledge has to do with the ability to act. Structural knowledge is the link between declarative and procedural knowledge and should be the prerequisite for understanding. Greca and Moreira (2000) made clear that for an understanding of the world through a working model, visuospatial representations play an important role.

The subject of flooding in the Netherlands is characterized by components that are spatially and functionally related on different scales. The questions are what knowledge structure and beliefs students have and how they reason about the causes, effects and risks of flooding? First of all, it is necessary to determine to what extent the knowledge structure consists of declarative, structural and procedural knowledge. In line with a previous study (Bosschaart et al., 2013) that showed low levels of knowledge about flooding in the surroundings, we expect that the knowledge structure will be fragmentary.

Reasoning

Reasoning and inferences

According to Wood, Bostrom, Convertino, Kovacs, and Linkov (2012b), mental models are characterized by both a structure component and a process component. This means that, on the one hand, mental models consist of a knowledge structure, while on the other hand mental models are used for reasoning and drawing inferences, which is an operation performed on that knowledge structure. A person's beliefs with respect to a certain topic could either be recalled from the knowledge structure about that topic or could also be the result of reasoned inferences that are based on what the person knows. Moreover, it is also possible that knowledge about a certain topic is used to make inferences with respect to another topic that has some resemblance with the original topic. Analogical reasoning and its role in cognitive processes has been emphasized by various authors (Collins & Gentner, 1987; Jones, Ross, Lynam, Perez, & Leitch, 2011; Wood et al., 2012b).

Because students have never experienced a breach in a dike and a subsequent flood, this is partly an unfamiliar domain they probably have never thought about. Therefore, it seems logical to assume that students' beliefs about flooding, which come up during an interview, are partly the result of reasoned inferences while answering questions. Possibly, the inferences are based on analogies because of their unfamiliarity with the subject.

Reasoning about flood related processes

The way lay people reason about the physical world is often characterized as common sense reasoning which is based on intuition whereby heuristics play an important role (Talanquer, 2006). Various researchers in this area assume that people make inferences through mental simulations rather than logical thinking (Forbus & Gentner, 1997). With respect to spatial mental models, Forbus and Gentner have stated that it is likely that "mental model reasoning is like watching a movie of a physical system with your mind's eye." (Forbus & Gentner, 1997, p. 1). For making this sort of inferences, people's mental models have to consist of images and topological representations of the components as well as the structural relations between the components (Greca & Moreira, 2000).

Processes related to flooding that could be mentally simulated take place at two levels of scale. The first level is more local and has to do with processes related to the way flooding water affects the dike and flows over the fields after the collapse of a dike. The other level concerns the navigational space (Tversky, 2003) whereby flooding water flows over the land surface on a regional scale. For the latter a spatial mental model consisting of a cognitive map is necessary.

The question is to what extent there exist mental simulations in the students' minds when reasoning about the subsequent events? Furthermore, it is important to determine whether students make use of visuospatial representations while reasoning about flooding. Additionally, it we try to determine what kind of heuristics or intuitive rules students use while making inferences.

Reasoning about trust in flood protection

Previous studies showed that in the Netherlands trust in flood defenses and in responsible risk managers is high. This applies to people in general as well as to 15-year-old students (Terpstra, 2011; Bosschaart et al., 2013). Trust plays an important role in risk perception, especially when people are lacking knowledge. Although trust shows similarity with affect, Terpstra (2011) made clear that cognitive evaluation of (flooding) risk is also related to trust. In this study, we try to determine how students describe verbally why their trust in flood protection is high and to what extent they make use of their mental model and of existing beliefs.

Research questions

Because previous quantitative studies showed that students' awareness of flood risk is low, and their trust in flood safety is high we are interested in the knowledge structures and beliefs on which these ideas are based. In this study, we try to explore the way students think about flood risk in their surroundings. Mental models are elicited in order to describe students' knowledge structures as well as their way of reasoning about flood risk. The main research question is: How do 15-year-old-students in flood prone areas in the Netherlands think about flood risk in their surroundings? In order to answer this question we will explore the following descriptive research questions:

> Research question 1: How salient is flood risk in their own surroundings among 15-year-old students in Culemborg and Gouda?
> Research question 2: What kind of mental model with respect to flood risk in the surroundings do 15-year-old students in Culemborg and Gouda have?

> Research question 3: How do 15-year-old students in Culemborg and Gouda reason and make inferences with respect to flood risk in their own surroundings?

Furthermore, we expect that flood risk salience will be low, students' mental models will be fragmentary and that students' beliefs are partly the result of reasoned inferences while answering questions.

Method

To explore the students' knowledge structures and the way they think about flood risk, the mental model approach, as described by Bostrom et al. (1992) and Morgan et al. (2002), was used. This method was applied in other studies with respect to various hazardous processes (Wagner, 2007; Zaksek & Arvai, 2004) in order to improve risk communication.

Research group

In order to involve students from different flooding areas, two schools were selected one in Gouda and one in Culemborg. The two locations differ in elevation, flood mechanism, flood history and topographical situation. In both schools 15-year-old students at pre-university education level (VWO) and senior general secondary education level (HAVO) participated in this study. In order to ensure that the participants came from various parts of the area, students were selected by postal code. Students were evenly divided between gender and school type. Prior to the interview students and their parents were informed by letter that the interview was part of a research project about the way students think in general about their surroundings. To avoid any form of prompting, the exact topic (flood risk), was not mentioned at all.

Interviews

Students were interviewed in couples of two. This had the advantage of a reassuring situation, but there was the drawback of students influencing each other. Each interview went on for approximately 45 minutes. Preceding the interview, students were ignorant about the topic of the interviews. In order to elicit students' mental models the interviews comprised two phases. The first phase of the interview consisted of two general questions in which the students were prompted as little as possible. The second phase of the interviews had a funnel sequence. This means that all interviews started with broad, general questions. Depending on the answers, these questions were followed by more specific questions and follow-up questions. The interview protocol is included in part 1 of the supplemental online material. All interviews were recorded and were taken by the same person, the first author. Subsequently, the interviews transcribed verbatim.

Measurements

Salience

The first question during the interview was aimed at finding out flood risk salience. At the start of the interview students only knew that the subject of the interview would be the surroundings of the school. Flooding or related aspects were not mentioned at all. Salience of flood hazards was measured by the extent to which students mention flooding as a potential personal threat relative to other dangers while looking at pictures of situations in the surroundings (the pictures are included in part 2 of the supplemental online material). The use of pictures in order to determine flood risk salience was applied to make clear that the question had to do with potential threats of concrete situations in the surroundings of the school. In this way, students were enabled to make associations between the surroundings and potential threats.

Students were shown nine pictures of situations in the surroundings that could be related to danger. The pictures showed potential threats like traffic situations, industries, disadvantaged neighborhoods and dikes and rivers. Some pictures showed more than one potential dangers. While looking at the pictures they were asked the following question: "In what picture or pictures a situation is shown in which there is at the moment, or could be in the future a dangerous or life-threatening situation for you?" Subsequently, they were asked to write down the causes of the threat in the indicated pictures. Students were told they were to choose none, one or more of the situations in the pictures. In order to avoid interaction between the students and imposing other people's beliefs, this task was performed in silence without the possibility of consultation. To analyze the results, the average number of pictures with a threatening situation that students mentioned, was determined. Furthermore, the causes of the threat that students mentioned were classified into six categories and were tallied.

Mental models

The mental model approach consists of a four-step process: (1) creating a knowledge diagram about flood risk with respect to the area under study; (2) eliciting students' mental models through semi-structured interviews; (3) mapping the knowledge and beliefs; and (4) identifying gaps and misconceptions.

For both areas, knowledge diagrams were created separately because the mechanisms behind flooding differ strongly. The design of both knowledge diagrams was based on the scenario method as described by Morgan et al. (2002). The main structure of the diagram (Tables 1 and 2) consists of four subsequent events describing two exposure processes and two effect processes: high water levels, dike bursts, flooding and effects for inhabitants. Each event is a prerequisite for the next event. In the knowledge diagram, the events are described by (1) concepts concerning their characteristic features (declarative

Table 1. The completeness of students' mental models in Culemborg.

	Chain of events				
	Exposure processes		Effect processes		
	High water ► levels	►Dike burst►	►Flooding►	►Effects for inhabitants	Mean % for each row
Characteristic features *(declarative knowledge)*	62%	46%	21%	40%	44%
Factors influencing the features *(structural knowledge)*	39%	8%	23%	20%	24%
Disaster Response	21%	4%	4%	36%	22%
Prevention and hazard adjustments	12%	20%	0%	13%	14%
Mean % for each column	34%	20%	19%	27%	25%

Table 2. The completeness of students' mental models in Gouda.

	Chain of events				
	Exposure processes		Effect processes		
	High water ► levels	►Dike burst►	►Flooding►	►Effects for inhabitants	Mean % for each row
Characteristic features *(declarative knowledge)*	14%	15%	15%	48%	20%
Factors influencing the features *(structural knowledge)*	15%	4%	13%	1%	11%
Disaster response	7%	2%	–	24%	13%
Prevention and hazard adjustments	0%	12%	12%	11%	7%
Mean% for each column	12%	9%	12%	21%	14%

knowledge); (2) concepts with respect to the factors influencing the features (structural knowledge); (3) concepts about long term control strategies with respect to prevention and hazard adjustments; and (4) short-term control strategies like the response to disaster warnings as well as the disaster itself. The group of concepts concerning control strategies consists partly of concepts that can be classified as procedural knowledge. Procedural knowledge includes the concepts that have to do with control strategies that relate to the actions of citizens themselves prior to and during a flood. The knowledge diagrams were firstly created on the basis of literature. In order to take the regional situation into full account, the diagrams were discussed with specialists of the regional water boards. Because of the dimensions both diagrams are not included.

During the first phase of the interview students were asked to tell everything they knew about flooding and flood risk in their surroundings. The second phase of the interview consisted of the following questions: (1) "What are the causes of flooding in the surroundings?"; (2) "Are the surroundings adequately protected against flooding?"; (3) "What are the effects of flooding in the surroundings?'; and (4) "Do you know what to do in case of a flooding?".

The transcriptions of the interviews were encoded by comparing them with the knowledge diagram. This was done by the first author. In order to take account of the inter-rater reliability all interviews were encoded independently by a second person with geographical background knowledge. Both coders agreed 82% (Culemborg) and 90% (Gouda) of the time. According to Bostrom et al. (1992), this is a reasonable agreement for a fine-grained coding-scheme like the knowledge diagram. On the basis of the encoded tables, the completeness, the substantive beliefs and gaps in students' mental models were established. Completeness was measured by determining the mean percentage of mentioned concepts for each category, event and type of knowledge in the knowledge diagram. Concepts that were mentioned by 50% or more of the students were defined as substantive beliefs. The gaps in students' mental models were determined by those concepts that were mentioned by less than 25% of the students.

Reasoning

Quotations in which students showed that they were able to describe their line of thought and inferences verbally were gathered. These quotations had to do with flood-related processes and trust. Those quotations whose content and purpose are repeatedly mentioned by students (more than twice), were selected. A selection of these quotations, which are illustrative of the way students' reason, is included. Furthermore, these quotations were analyzed in order to make clear how students make use of their mental model and in what way students make use of mental simulations and heuristics.

Results

Flood risk salience (Research question 1)

On average, students in Culemborg named 2.5 out of 9 situations in the pictures as threatening. Ninety percent of the students mentioned traffic as a cause of the threat. Air pollution and social unrest were mentioned by 30% of the students. A mere 8% of the students mentioned flooding as a threat. In broad terms, the results in Gouda were the same. On average, students named 1 out of 9 situations in the pictures as threatening. Ninety percent of the students mentioned air pollution as a cause of the threat. Traffic was mentioned by 60% of the students and industrial explosions by 12%. Again a mere 8% of the students mentioned flooding as a threat.

Mental models (Research question 2)

Mental models among students in Culemborg

During the first phase of the interviews, the phase without any prompting, hardly any concepts from the knowledge diagram were mentioned. The only concept mentioned by the majority of the students had to do with the evacuation of their relatives during a period of high water discharges in January 1995. Table 1 shows the completeness of students' mental models and is the result of the interviews in the first and second phase. In general, students' mental models consist on average of 25% of the concepts of the knowledge diagram, but there are differences between the four events. On average, students mentioned 34% of the concepts with respect to high water levels and 27% of the concepts concerning effects. This is more than the concepts with respect to dike bursts (20%) and flooding (19%). This may be due to students' experience with higher water levels and the relative ease to comprehend effects for themselves. Processes like dike bursts and flooding are much more difficult to imagine and hardly appear in their mental models. Furthermore, concepts concerning the characteristic features of the events (44%) were mentioned twice as much as concepts that affect the events and concepts with respect to control strategies in the short term. Because concepts concerning properties deal with declarative knowledge and concepts that influence the properties deal with structural knowledge, it is clear that students primarily possess declarative knowledge while structural knowledge occurs to a lesser extent. Concepts with respect to prevention and hazard adjustments in the long term were mentioned the least. On average, students mentioned 24% (not visible in Table 1) of the concepts with respect to procedural knowledge, knowledge concerning how to act preceding and during a flood.

Of all concepts (59 in total), 12 were mentioned by 50% or more of the students and could be identified as substantive beliefs, of which 6 features, 4 factors that influence features and 2 control strategies. Just like completeness, most of the substantive beliefs refer to high water levels and the effects of flooding. The substantive belief about the relation between the dike burst location and inundation depth turned out to be a misconception.

Eighty three% of students think that the farther away from the dike burst location, the lower the inundation depth. In reality this relation is the opposite.

The gaps in the students' mental models (concepts mentioned by 25% of the students or less) concern 23 of all concepts. Because students' mental models do not consist of concepts about dike failure upstream, the influence of lateral dikes on flooding water, and the correct inundation depths, it seems plausible to conclude that students do not have a spatial image of the navigational space concerning the elevation gradient of the land surface in relation to the height of the flood water. Students are not able to create a correct spatial image when they are asked about it. With respect to the effects of flooding, students' mental models are incomplete and incorrect. Students' mental models hardly consist of concepts with respect to important control strategies in the long term and the short term. Elements in the area concerning adaptation to potential flooding in the past, like terps or dwelling hills, were not mentioned. Some students mistakenly think that as a result of flooding there are only victims near the dike burst location and this would be limited to children and elderly people. The few students that mentioned an important policy element with respect to flood prevention ("room for the river project") appeared not to understand that policy. They thought that within a few years all the dikes could be moved farther from the river, as if this would be an easy job. Finally, it is important to emphasize that the incompleteness of and the gaps in the students' mental models result in contradictory beliefs. While the majority of the students believe that the inundation height will be limited to tenths of centimeters just around the dike burst location, most of them think, wherever they are, it is necessary to be evacuated or flee to the upper floor. Therefore, students' mental models with respect to flooding and flood risk seem to be inconsistent. (A table with all substantive beliefs, gaps and misconceptions in Culemborg is available in part 3 of the supplementary material.)

Mental models among students in Gouda

Just like in Culemborg, hardly any concepts were mentioned during the first phase of the interviews. The only concept mentioned by almost half of the students had to do with the elevation below the sealevel of Gouda and its surroundings. Table 2 shows the completeness of students' mental models as a result of the interviews during the first and second phases. In general, students' mental models consist on average of 14% of the concepts of the knowledge diagram. Concepts concerning the effects of flooding (21%) were mentioned slightly more than with respect to the other events. As in the case of Culemborg, concepts concerning the characteristic features of the events (20%) were mentioned twice as much as concepts that are influencing the events and concepts with respect to disaster response (control strategies in the short term). Concepts with respect to hazard adjustments and prevention (control strategies in the long term) were hardly mentioned. On average, students mentioned 14% (not visible in Table 2) of the concepts with respect to procedural knowledge, knowledge concerning how to act preceding and during a flood.

Of all concepts (91 in total), eight were mentioned by 50% or more of the students and could be identified as substantive beliefs, of which seven were features, and one was a control strategy. Just like completeness, most of the substantive beliefs refer to the effects of flooding. Apparently, the fact that students can easily imagine the low elevation of the land surface relative to the sea level enables them to make realistic inferences about the inundation depth as well as the effects of flooding, although they never experienced such a situation. The gaps in the mental models are related to all four events and the constituent concepts. It is necessary to emphasize that the threat of flooding in the situation of Gouda is very complicated because the threat is caused by different mechanisms. This partly explains the incompleteness of students' mental models. Furthermore, the gaps make clear that students only have a general conception with respect to flooding around Gouda. Local and regional differences with respect to the elevation and inundation depth are largely lacking. With respect to the river Hollandse IJssel, which flows past Gouda, there exists a remarkable gap in the mental models and a misconception about the nature of the threat. Some students (27%) are not aware of the presence of the river which is remarkable because it is only 500 m from the school and there are high dikes alongside the river. Other students (70%) cannot imagine the threat posed by the river. In spite of the fact that all students know about the 1953 flood disaster, they do not realize that the river Hollandse IJssel constituted a considerable threat during this worst flood disaster in recent times. (A table with all substantive beliefs, gaps and misconceptions in Gouda is available in part 3 of the supplementary online material.)

Reasoning (Research question 3)

Table 3 comprises nine quotations with respect to flooding as a process and five quotations with respect to trust in flood protection. These quotations are illustrative of the way students reason about the two flood related aspects. Quotations 1, 8, 10 and 13 show the limited knowledge structure and the unfamiliarity with the domain, of which they become conscious during the interview. Furthermore, these quotations make clear that students make inferences while answering the questions, instead of having beliefs about major aspects of flood risk.

Quotation 2 shows that students in Culemborg underestimate the river discharges during a period of high water. They cannot imagine the huge amount of water which is threatening them. Quotation 3 shows the way students in Culemborg mistakenly make inferences about the way water spreads over the surface and infiltrates the soil, by using mental simulations. At the same time, this quotation shows the use of rule-based inferences, by using a heuristic that possibly originates from everyday experiences with the way water and soil interact. Therefore, this is an example of analogical reasoning.

Quotation 4 shows the general notion that students in Gouda have with respect to the effects of climate change. The inference about the melting ice, the rising sea-level and the flooding of the Netherlands is a well-known image that is repeatedly presented in the media.

Quotation 5 is typical of the way students in Gouda describe verbally the way flooding occurs by using mental simulations that take place in the navigational space. For this kind of mental simulation, a mental map or visuospatial representation of the area is required.

Although quotation 5 is based on the correct assumption that Gouda is quite far from the coast, this student ignores the threat of the river Hollandse IJssel which is close to the school. This quotation is therefore typical of the general notion that students have about flooding around Gouda. Students from Culemborg were not able to make inferences about flooding that referred to the navigational space of the surroundings of the school.

Quotations 6 and 7 show the way students in Gouda imagine the devastating effect of flooding water. These quotations are representative of what many of the interviewed students think and make clear the ease with which students use the intuitive rule that the high flow rate of the flooding water causes destruction and casualties. Because the elevation of Gouda itself is not as low as students think, this makes clear that students' mental representation of height differences in their surroundings is wrong. Quotation 9 is typical

Table 3. Students' quotations with respect to flood related processes and trust in flood protection.

Quotations with respect to flood related processes	Conscious ignorance	Mental simulation	Heuristic or intuitive rule
What causes the high-water levels in the river Lek and Culemborg?			
1 Low tide and high tide, no that's near the sea... the moon.... does it have something to do with the rivers?	X		
What is the height of the floodwater in Culemborg when the dike bursts?			
2 I think you will have wet feet, but nothing serious because it's only a river. It will be a terrible mess but not that much. But after seawater flooding, there will be many more problems.			X
3 I think it won't even reach the school. If you pour a bucket of water on the ground, it's gone directly, a big amount of water will absorbed by the ground and it will be stopped by the town.		X	X
What would cause a flood in Gouda?			
4 When the polar ice keeps on melting, it is likely that the water will reach Amersfoort, if our dikes and flood barriers won't be high enough."			X
5 I have the impression that Gouda is quite far from the coast. In case of a flooding, I think it won't reach Gouda that soon, it takes a while before the water will be there so that we can be evacuated.		X	X
What would, in your opinion, be the effects of flooding in Gouda?			
6 Many casualties, the currents will be quite strong and the people will be dragged along.		X	X
7 If a dike breaks, first of all the water will flow to Gouda and surroundings, because it is the lowest point.		X	X
Do you know what is the best thing you can do during a flood?			
8 Stay at home, after all, or yes, take the most valuable things and go somewhere dry, I don't know, such a situation is very rare, you don't know what you will do because you have never experienced this.	X		
9 Go to the top floor, I would go to the roof of my house			X
Quotations with respect to trust in safety measures			
Why do you think that the surroundings of the school are protected well against flooding?			
10 Yes, but that's what I think, but I'm not sure whether it's true	X		
11 The Netherlands is a country that is best protected against floods, because we have more or less invented the dikes. In other countries they say that we are leading. Centuries ago we reclaimed polders etc. So we have much experience. Other countries are less well protected.			X
12 The dunes are made higher every year, I think. Well perhaps not every year but they will definitely increase the height when the sealevel rises The Dutch government is lazy (...) but I don't think they will allow the flooding of a whole society.			X
Do you know what is the best thing to do during a flood?			
13 No, not really. But instinct will tell you to go the highest part of something. The Dutch are good swimmers, but after many hours you will be exhausted, But I think that the fire brigade, in our country, will soon come to the rescue.	X		X
14 But I do think that if it happens there will be a sort of weather alarm so that you will be warned in advance. So, many people will be able to flee from the threatened area by car.			X

of students in Gouda that make use of the safety rule that counts during a flood: the higher the safer.

Quotation 10 makes clear that students admit that trust is based on a feeling rather than knowledge. Quotations 11 and 12 illustrate the general feeling that the water authorities in the Netherlands are very well prepared and the country is effectively protected against flooding. Furthermore, quotation 11 makes clear that the presence of dikes ensures that students feel secure. Quotation 13 shows the intuitive or heuristic way in which students expect from the authorities absolute safety with respect to prevention and, in the unthinkable situation of a flood, they expect a competent disaster response from the authorities. Within this framework it is noteworthy that almost 90% of the students are not aware of the existence of the local water authorities.

Quotation 14 shows the intuitive or heuristic way in which students expect disaster response from the authorities as well the possibility to be evacuated. It seems that they are used to warnings in advance in the case of threatening weather situations and they expect that this will also happen in an unfamiliar event of flooding. Therefore, this is an example of analogical reasoning.

Conclusions and discussion

In this qualitative study, we have tried to answer the main research question with respect to the way 15-year-old students think about flood risk in their surroundings. Thinking about flood risk has been operationalized by distinguishing three aspects of students' thinking: salience, mental models and reasoning.

The salience or prominence of flooding and flood risk in students' minds is low. Not more than 8% of the students, who were prompted by pictures with various potential dangers in the surroundings, mentioned flooding and flood risks. On the other hand, traffic and air pollution were much more salient. The low salience of flooding is in line with low flood risk perceptions among Dutch citizens in general (Terpstra, 2009) and Dutch students in particular (Bosschaart et al., 2013). Terpstra and Gutteling (2008) also found low salience with respect to flooding, although it must be said that their concept of salience was measured differently. Furthermore, our results correspond with the general assumption that man-made hazards cause much more concern than natural hazards like flooding (Wachinger & Renn, 2010).

Students' mental models turn out to be very fragmentary in both Culemborg and Gouda. This is in accordance with our expectations derived from a previous study (Bosschaart et al., 2013). When comparing the mental models of students in Culemborg and Gouda, we should take into account the differences in flood mechanisms and topographical situation. The much more complex situation in Gouda, with threats from both the sea and the rivers, could explain why students' mental models in Gouda are more fragmentary than in Culemborg. Nevertheless, students' mental models in both Gouda and Culemborg show similarities with respect to the types of knowledge and the gaps in the knowledge structure.

The knowledge structure consists mainly of declarative or factual knowledge. Structural knowledge, about the connections between the facts and about causes and effects, appears much less in the mental models. Knowledge about control strategies with respect to prevention and disaster response are largely lacking. This is also applicable to procedural knowledge about how to act before and during a flood. This is not surprising because hardly any attention is paid to the eventuality of flooding as well as the necessary disaster response (Heems & Kothuis, 2012; Terpstra, 2009). These results are in accordance with the results of the mental model study of Lave and Lave (1991) in the United States. They also found that people know very little about floods, flood mitigation and flood preparedness in their surroundings.

In the students' mental models, in both Culemborg and Gouda, important local and regional knowledge based on visuospatial representations is lacking just like knowledge about dikes and dike bursts. The latter is illustrated by the fact that just a few students are able to imagine and describe verbally what processes play a role when a dike bursts.

Notwithstanding the similarities, there are also differences between students' mental models in the two areas. Students from Culemborg are able to mention, when asked, the river as the source of the threat, but they cannot estimate the severity of the threat. Students completely underestimate the inundation depth. On the other hand, students from Gouda are convinced of the severity of a potential flood, but they hardly know where the threat is coming from. The low elevation of Gouda and surroundings below sea level seems to determine students' high estimation of the flood effects. However, most students underestimate the threat of the nearby river Hollandse IJssel.

In this study, students' quotations are used to describe the way they reason about flood risk. These quotations make clear that they are becoming aware of their ignorance about flood risk while answering the questions. This is in accordance with the incomplete mental models and with the low salience with respect to flood risk. Therefore, it seems plausible to assume that students' beliefs about flooding were partly generated during the interview and were not part of their mental model prior to the interview. Besides, it explains why students make use of heuristics and analogical reasoning based on everyday experience while making inferences about flooding. This is in accordance with Reiner, Slotta, Chi, and Resnick (2000) who made clear that students' knowledge and reasoning about naive physics is based on everyday experience.

In describing their thoughts, some of the students made use of mental simulations, whereby visuospatial representations and heuristics seemed to play a role. Students' heuristics with respect to flood risk, which were based on analogies from everyday experiences, were misleading. This is in accordance with Bostrom (2008) who made clear that comparisons and analogies with respect to hazardous processes could also be deceptive. Of the students that made use of mental simulations, only those from Gouda seemed to apply this to the navigational space. However, their mental representations were restricted to a general image of the elevation of the surroundings without a correct representation of local differences in elevation.

In both Culemborg and Gouda, students' knowledge structures and quotations show that the high trust in flood protection can be characterized as blind faith. Students do not know about the regional water authorities nor about their efforts with respect to dike improvement. However, the quotations make clear that students expect that authorities to provide adequate protection and to be well prepared in case of flooding. It seems to be a sort of analogical reasoning. Because students have never experienced any threat of flooding they compare this unfamiliar situation with what they can expect of the authorities in other extreme situations that they are more familiar with. Next to blind faith, the levee effect (Bell, Greene, Fisher, & Baum, 2001; Tobin, 1995) accounts for the high trust in water protection. Tobin describes this effect as the false sense of security that inhabitants of flood prone areas perceive because of the presence of dikes or levees.

The limitations of this study with respect to the way mental models were elicited should be taken into account. Because the interviews started with a picture question, this may have prompted some ideas. Next to this, students may have prompted each other because they were interviewed in couples. Nevertheless, students' mental models turned out to have a piecemeal character. The challenge of mental model interviews is to elicit the knowledge structure on which people's decision making and actions are based. Jones et al. (2011) made clear that there could be a difference between what people say during an interview and the tacit knowledge structure on which they base their decisions. This difference could be caused by the way in which people, while answering a question, make abstract representations in their working memory that are based on the mental model in their long-term memory. Nevertheless, the indirect elicitation method using interviews and comparing lay peoples' mental models to a knowledge diagram, has frequently been used with respect to risk communication research (Wood et al., 2012a). Because of the small database, the results cannot be generalized. In spite of this, the results provide useful insight into how students from two different flood prone areas in the Netherlands think about flood risk in their surroundings.

Geography education

Flooding in the Netherlands can be characterized as a low-probability/high-effect event, whereby the vulnerability of the inhabitants is enlarged by the fact that they are not really aware of the risks of flooding. It is important to generate this awareness in such a way that people know what the potential effects of flooding are, what they can expect of the authorities, and how they should act themselves, before and during a flood. If geography education has the ambition to contribute to flood risk awareness, the contents of courses and the pedagogy should be reconsidered. Because students' mental models turn out to be fragmentary and hardly consist of structural and procedural knowledge, it is important to adapt the contents of geography education. Just like Wagner (2007), who studied the mental models of flash floods in the Alps, we recommend that the local and regional situation of the school surroundings should play a crucial role, because of the major impact on the causes and effects of flooding. This is in line with the results of a previous study that showed that knowledge about flooding in people's own surroundings has a positive effect on flood risk perception (Bosschaart et al., 2013). Just like Reinfried (2006) and Lane and Coutts, 2012, we assume that knowledge about students' existing mental models is essential for developing effective teaching methods. Therefore, it is necessary to take into account students' misconceptions, the way they make use of heuristics and how they could be enabled to construct a visuospatial representation that enhances spatial reasoning and the use of mental simulations. The visualization of flooding processes in the local situation is very important. Once again, this is in accordance with Wagner (2007). Further study is needed to develop a new approach and to determine the effects of new pedagogical methods with respect to flood risk awareness. It is a great challenge for geography education to develop a course to contribute to enhancing flood risk awareness by taking into account the aforementioned aspects and by combining cognitive with affective factors (Bosschaart et al., 2013; Terpstra, 2011).

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No potential conflict of interest was reported by the authors.

Supplemental data

Supplemental data for this article can be accessed here.

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