Designing a flood-risk education program in the Netherlands

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ABSTRACT
This study focused on designing a flood-risk education program to enhance 15-year-old students’ flood-risk perception. In the flood-risk education program, learning processes were modeled in such a way that the arousal of moderate levels of fear should prompt experiential and analytical information processing. In this way, understanding of flood risk in the surroundings should prompt students’ threat and coping appraisal. To accomplish this, the program consisted of a variety of student-directed parts, such as serious games and flood simulations. The design of the program was based on theoretical understandings from learning theory, information processing, and risk communication. Furthermore, empirical findings about students’ risk perceptions were incorporated. The design process was guided by the principles of Educational Design Research and had an iterative character.

KEYWORDS
flood-risk perception; belief change; blended learning; information processing

Introduction
Worldwide, flooding is one of the main natural hazards that causes tremendous damage and a great many casualties. Due to climate change, it is expected that flood risks increase in low-lying coastal areas and flood plains (Maaskant, Jonkman, & Bouwer, 2009). This also applies to the Netherlands where 25% of the country lies below sea level and about two-thirds would be flooded frequently without flood defenses. The probability of flooding will increase due to sea level rise and increased river discharges (Bouwer & Vellinga, 2007; Pinter, van der Ploeg, Schweigert, & Hoefer, 2006). Besides the consequences of flooding, both loss of lives and economic damage will increase because of the population growth in the flood-prone areas (Maaskant et al., 2009; te Linde, Bubeck, Dekkers, de Moel, & Aerts, 2011).

Although the Netherlands is well known for its low elevations and zealous efforts to protect the country against flooding, the Dutch population is hardly aware that flooding still is a threat that must be reckoned with (OECD, 2014). For many people flooding belongs to the past because they assume that authorities have done everything they can to protect the country, as if safety could be guaranteed. Although people in the Netherlands live in a country with dikes and barriers combined with an age-old flood history, flood risk is not salient at all; even thinking of flooding would not evoke fear. This conception is deeply embedded in society and Heems and Kothuis (2012) call this “the myth of dry feet.” Previous studies (Bosschaart, Kuiper, & van der Schee, 2015; Bosschaart, Kuiper, van der Schee, & Schoonenboom, 2013;) showed that this myth also applies to Dutch students. Within this framework education and communication about this risk is a challenging task.

This study covers the role formal secondary education, i.e., geography education, can play in achieving or facilitating the goals of flood-risk communication in the Netherlands. Until now, the
opportunities of formal education with respect to flood-risk communication are hardly acknowledged. It seems obvious that geography as a compulsory subject in the first three years of secondary education in the Netherlands should play an important role on this topic.

Therefore, this study aims at designing a flood-risk education program that contributes to raising students’ flood-risk perceptions and their preparedness intentions. The main task of this program will be to deconstruct “the myth of dry feet” (Heems & Kothuis, 2012). Lindell and Perry (2004) put this into more tangible words:

The purpose of hazard communications is to prompt people to redefine the situation from one in which the environment is primarily positive to one in which the environment is threatening. The process of redefining the situation leads to the identification of possible actions that could be taken and concludes with decisions about appropriate responses to the threat. (p. 46)

Until now, risk communication as well as geography education with respect to flood risk paid attention to the Netherlands in general (Bosschaart et al., 2013). There are various reasons to adjust a flood-risk program on the regional situation. First, the flood-prone areas in the Netherlands differ enormously with respect to elevation, flood mechanism, flood protection, and vulnerability and hence, in necessary protective action. Besides, previous studies have shown that students in the Netherlands are well aware of flood risk in the Netherlands in general. The optimistic bias is applicable to flood risk perception concerning their own surroundings (Bosschaart et al., 2013). Therefore, the program to be developed was adjusted to a particular location of schools in a flood-prone area in the Netherlands: West-Friesland, a region in the province of North-Holland. The program was designed with the characteristics of this region in mind and making use of information of the regional water board, the authorities that are responsible for water safety.

Because the design of a flood-risk education program is complex and challenging, we have based the design process on the principles of Educational Design Research (EDR). According to Plomp and Nieven (2009) systematic study of designing, developing, and evaluating an educational intervention is necessary in order to be successful.

In the Netherlands various authors have dealt with environmental education in relation to sustainable development (Hesselink, van Kempen, & Wals, 2000; Kopnina, 2014). As the focus of environmental education with respect to flood-risk perception differs from education concerning sustainable development, the work of these authors was not incorporated.

**Method and aims**

The main research question of this study is: *What are the characteristics of a flood-risk education program in the Netherlands that contributes to improving 15-year-old students’ personal flood-risk perceptions and flood-preparedness intentions?* In developing a flood-risk education program or product, we have reasoned from the key principles of Educational Design Research (Plomp & Nieven, 2009; van den Akker, Gravemeijer, McKenney, & Nieven, 2006). This type of research can be characterized as interventionist, iterative, involvement of practitioners, process-oriented, utility-oriented, and theory-oriented. This means that next to the practical aim of an effective flood-risk education program, this study focuses on finding valid design principles as the scientific yield of this type of research. Design principles are preliminary assumptions that represent the essential functions and characteristics of the program to be developed. These “substantive” principles are also called “heuristic statements” or “intervention theory” (Wademan, 2005).

Figure 1 shows the way the main research question has been elaborated into seven more specific research questions, as well as the iterative character of the design process. This article seeks to address questions 1–5; questions 6 and 7 will be addressed in a forthcoming article. During each stage the product of the prior stage has been evaluated formatively on the basis of the specific research question. During focus group discussions seven geography teachers and four geography teacher educators evaluated the product. With respect to the research questions 3, 4, and 5, the participants gave their comments individually by using the format of a SWOT-analysis after which a group discussion took place. The
discussions were recorded, reported, and analyzed. The representative themes were listed. The participating geography teachers came from schools that are located in the area for which the flood-risk education program was developed and from schools in flood-prone areas in the same province. Because of a tight schedule it was decided to limit the formative evaluation to teachers and educationists. The evaluation could have benefited from the inclusion of students' evaluations.

The first stage consisted of an analysis of theoretical understandings and empirical findings. This resulted in a set of tentative design principles and a global design of the program. The global design (appendix 1) consisted of a general description of the aims, pedagogy, and content of the flood-risk education program and the role of teacher and students. The development of the flood-risk education program took place during stages 2, 3, and 4. Stage 2 consisted of evaluating the global design. This resulted in adapting the design principles and pedagogical approach and elaborating the content of the program. During the third and fourth stages the flood-risk education program, consisting of teaching
and learning material\textsuperscript{1} for use in the classroom, was evaluated and adapted. The fifth stage about the actual effectiveness of the program will be reported in a separate study.

This study is part of a PhD study by the first author, which coincides with a nationwide program by the Ministry of Infrastructure & Environment and the water boards to enhance flood-risk awareness. The authors as a team combine their expertise on design research (Wilmad Kuiper), pedagogical research with respect to geography (Joop van der Schee) and teaching geography as well as physical geography (Adwin Bosschaart), which is necessary for this type of research.

**Analysis**

The main aim of the flood-risk education program is raising awareness and strengthening risk perception and preparedness intentions. Therefore, we based the design on empirical findings about the way Dutch students perceive flood risk as well as theoretical understandings concerning learning theory, information processing, and risk communication.

**Students’ perceptions and mental models with respect to flood risk in the Netherlands**

Previous studies (Bosschaart et al., 2015; Bosschaart et al., 2013;) made clear that although Dutch students know there is a flood-risk in the Netherlands in general, they hardly apply this to their own situation. Students’ personal flood-risk perception is low and they hardly perceive fear when thinking about flood risk. Furthermore, students’ trust in water safety is high and their level of knowledge about flooding in the surroundings is low. Regression analysis made clear that students’ flood risk perception is influenced positively by fear and knowledge. Furthermore, it has been found that flood risk is not at all salient, even when prompting students with images of dikes and rivers at familiar spots in the surroundings. This makes clear that elements related to the river and flood-protection are not associated with thoughts about flood risk, let alone flood-related feelings. Therefore, we may conclude that both the affect heuristic and the availability heuristic, that function as “mental shortcuts” (Slovic, Finucane, Peters, & MacGregor, 2004), are applicable to students’ flood-risk perception in the Netherlands. This implies that intuitive feelings and (the lack of) experienced events largely determine students’ perceptions.

According to Bostrom, Fischhoff, and Morgan (1992) and McClure, Walkey, and Allen (1999) the extent to which mental models are sophisticated determines risk perceptions. Students’ mental models in two Dutch cities in flood-prone areas, turned out to be fragmentary and consisted mainly of factual or declarative knowledge (Bosschaart et al., 2015). Knowledge consisting of understandings about the where and why of flooding and its effects is lacking largely. Mental images of dikes and their location are lacking in relation to height differences in the surroundings, which play an important role in understanding the inundation and inundation depths. This also applies to mental simulations of the processes connected with dike bursts and flooding. Based on the aforementioned, it is not surprising that students possess fundamental misconceptions with respect to flooding and its consequences and that the way they reason about flooding is based on analogies and heuristics. Because of a high degree of ignorance with respect to prevention and disaster response, students’ trust in water safety can be characterized as blind faith.

**Learning theory**

According to Illeris (2007) various learning theories emphasize different aspects of learning. Therefore, many learning theories are more or less one-sided. Illeris has tried to combine these existing theories into his model of the “three dimensions of learning,” consisting of the cognitive, emotional, and social dimensions of learning. With respect to internal learning, Illeris distinguishes a cognitive and an emotional dimension. Besides a psychological or internal process, social interaction is needed for learning to take place. Based on the work of Piaget and Kolb, Illeris (2007) distinguishes two learning processes: assimilation and accommodation. Assimilation is the type of learning whereby knowledge is added to the existing mental schemes, and accommodation takes place when the existing schemes do not
correspond to the presented knowledge. In the latter case, students need to reconstruct the existing schemes. Compared to assimilative learning, accommodative learning is more demanding and challenging and more mental energy is needed. Therefore, there is a tendency to avoid this type of learning unless people are convinced to do so. Accommodative learning is facilitated when teaching methods are problem oriented and students can co-determine the direction of what is to take place and teachers have a more or less supportive role. According to Illeris (2007), cognitive and emotional processes intertwine, especially with respect to attitudes. Emotions affect interpretations and interpretations prompt emotions. It is said that positive emotions intensify existing knowledge structures through assimilative learning, whereas negative emotions prompt problem solving through accommodative learning.

Knowledge construction takes place by building on existing knowledge; therefore, it is important for the teacher and the student to know to what extent the existing knowledge consists of misconceptions, otherwise, these misconceptions operate as a barrier to successful learning. The social dimension in Illeris’ (2007) model builds on the ideas of Piaget and Vygotsky. Vygotsky has stated that mental operations have a social-communicative origin and thinking is restructured when it is expressed into language. Because mental concepts arise in the dialogue between children and adults, but also among children, verbalizing plays an important role. In order to put Illeris’ (2007) model into practice, we assume that learning should be blended.

**Information processing**

In social and cognitive psychology various dual process models are used to describe the way information processing takes place (Smith & Decoster, 2000). Under normal circumstances people process information heuristically or associatively by using simple rules of thumb and making quick evaluations based on spontaneous associations, experiences, and intuition. When the situation or the information causes more arousal and makes one feel threatened, the information will be processed systematically or analytically. This mode of information processing can be characterized as deliberate, analytical, and effortful, and will only take place when there is enough time and cognitive capacity.

According to the Elaboration Likelihood Model (Petty & Cacioppo, 1986) and the Heuristic-Systematic Information Processing Model (Chaiken, 1987) the chance that communication will lead to persuasion and enduring attitude change is enhanced when information is processed systematically. Motivation and the ability to comprehend are a prerequisite for this mode of information processing to take place. Heuristic processing would lead to bias and to not more than temporary attitude change. On the other hand, Smith and Decoster (2000) make clear that there are also dual-process models that state that both modes of information processing are necessary in order to process the information successfully. Finucane, Peters, and Slovic (2003) described this as the “dance of affect and reason” and Slovic, Finucane, Peters, and MacGregor (2004, p. 314) add to this that “it is unlikely that we can employ analytic thinking rationally without guidance of affect somewhere along the line.” According to Visschers and Meertens (2008) the first spontaneous reaction to a risk is affective and has to do with gut feeling and prior experience. Also Zajonc (1980) has emphasized the affective primacy, and this inescapable affective reaction influences the nature of the continuation of information processing. Besides, Loewenstein, Weber, Hsee, and Welch (2001) made clear that affective response could also be the result of cognitive evaluations.

**Risk communication**

With respect to risk communication many authors have emphasized the importance of incorporating the two modes of information processing (Marx et al., 2007; Visschers & Meertens, 2008; Zaalberg, Midden, Meijnders, & McCalley, 2009). Possibly the most apparent advocates of this approach are Slovic and colleagues (2004).

In situations where people do not have experience with a hazard and the probability of the hazard is low, cues from the environment are mostly reassuring. Then, risk communication or risk education is
the only way to influence people’s risk perceptions. The Protective Action Decision Model (PADM; Lindell & Perry, 2004) describes the way people decide about protective actions as a stepwise process. This process starts with the reception of, attention to, and comprehension of information. These so-called pre-decisional processes determine subsequently people’s threat appraisal, their assessment of the personal relevance and the assessment of potential coping behavior. In order to design successful risk communication, Lindell and Perry have stressed the importance of taking into account all these subsequent steps.

When people are confronted with information that is contradictory to their existing knowledge, they often try to find a justification for their existing beliefs (Lindell & Perry, 2004). This is called the confirmation bias. Furthermore, the intrusiveness of the information determines the way people are inclined to process the information and adapt their beliefs. Within this framework Lazarus (1988) made clear that when information processing has no connection with personal stakes, “knowledge is cold cognition (p. 282).”

According to the Protection Motivation Theory (PMT; Rogers, 1983) the arousal of fear could stimulate cognitive evaluation of the threat and the response. However, Ruiter, Abraham, and Kok (2001) made clear that fear appeal could also have inhibiting effects on protection motivation. When the level of fear is too high, the cognitive response could lead to ignoring or denial of the threat. This type of response is called “emotion-focused coping.” “Problem-focused coping,” the strategy to reduce the physical threat or vulnerability, is the adaptive response where risk communication is aiming for.

Various authors have emphasized the effect of previous experience with flood hazards on risk perception (Grothmann & Reusswig, 2006; Siegrist & Gutscher, 2006; Terpstra, Lindell, & Gutteling, 2009). In case people have no experience with a hazard because of the low frequency of occurrence, risk communication could focus on producing vicarious experiences through experimental manipulation. A traditional way is the use of fear-evoking images. In an experimental study Terpstra et al., (2009) found modest results. Zaalberg et al. (2009) suggested the use of 3D-technology in order to mimic a disaster experience that is experienced as “real.” A high-end virtual environment should not only produce bodily experiences but also emotional arousal. In the aforementioned, risk perception has been described as an internal construction. On the other hand Joffe (2003) has emphasized that the formation of people’s beliefs with respect to risks is guided by ideas and judgments that are predominant within related groups: “Explanations and judgments are not constructed within individual minds but in the ‘unceasing babble’, the ‘permanent dialogue’ that people have with each other and with institutions.” (Joffe, 2003; p.68).

Breakwell (2001) has called this the “subcultural base for any individual’s mental model (p. 344).” In Rohrmann’s risk communication model (Rohrmann, 2000) the societal discourse plays an important role.

**Outcomes of the design process**

**Underpinning of the flood-risk education program**

In order to design a flood-risk education program that contributes to belief change with respect to flood-risk perception and preparedness intentions, it is necessary to consider the way people think and judge regarding this topic as a stepwise process: (1) extending knowledge and understanding about flood risk; (2) raising awareness and strengthening personal flood-risk perception; and (3) influencing preparedness intentions (Figure 2). It must be emphasized that the cognitions concerning the first step differ from those with respect to step 2 and step 3. Whereas the first step focuses on information processing that should lead to knowledge about the way things are and how they work, step 2 and 3 deal with the appraisal or evaluation of that knowledge in relation to personal well-being.

Figure 2 shows the sequence of steps as well as the obstacles that are applicable to that step. We assume that presenting information not automatically leads to knowledge and understanding.
Furthermore, knowledge and understanding do not automatically lead to awareness and personal risk perception. Finally, risk perception does not automatically lead to preparedness intentions. In order to overcome these obstacles, we assume that a combination of both analytical and experiential information processing has to be initiated in such a way that both assimilative and accommodative learning can take place. In the stepwise process, analytical and experiential information processing are intertwined and are a requisite for proceeding the sequence. This means that we assume that the conscious analysis of information (step 1) will be initiated by intrusive information about flooding, like virtual dike breaches and flood simulations. The analysis of intrusive information, which will enhance knowledge and understanding about flooding in the surroundings, should in turn evoke affective reactions that motivate students to appraise the threat of flooding and the coping possibilities. The challenge lies in selecting and presenting information in such a way that moderate levels of fear are evoked. It must be emphasized that the stepwise process is not necessarily linear. Following Lazarus and Smith (1988), we assume that knowledge and appraisal, although different kinds of cognition, could function simultaneously.

In the course of the research process the design principles evolved and were sharpened. Initially, we thought that the essential functions and characteristics of the program could best be described with the principles motivation, systematic processing, and interaction with the surroundings. This stemmed from empirical understandings and the first reading of the literature. In hindsight, after evaluating the substantive part of the design process, we assume that the design principles are affect, availability, and blended learning. Affect can be described as feelings of “goodness” or “badness” that are tagged to mental images (Slovic et al., 2004). These feelings influence information processing and the perception of risk. Availability has to do with the salience, conceivability, and understanding of flood risk. With respect to blended learning we use a wide interpretation, which means a variety of pedagogical methods. Because learning that contributes to both knowledge and understanding as well as belief change is the result of learning activities that should prompt the two modes of information processing, all three dimensions of learning (Illeris, 2007) should be dealt with (see also section “Description of the design process and the design principles”).

**Flood-risk education program**

The flood-risk education program consists of teaching and learning material that is designed for 15-year-old students at pre-university education level (VWO) and senior general education level (HAVO).

**Pedagogy**

The pedagogical approach aims at evoking both experiential and analytical information processing. Therefore, a variety of learning activities or mental processes is needed that facilitates both types of information processing (Figure 3). These learning activities are combined within the student-directed parts and reinforce each other. During the first four lessons, teacher-directed learning parts are alternated with student-directed parts. The last three lessons consist of inquiry-based group projects that
are largely student-directed. In the description of the student-directed parts it will be made clear how the various learning activities play a role in the successive parts.

**Content**

The content of the program has been adapted to the regional and local setting of the participating schools. The threat of flooding has been elaborated as a chain of successive events that take place prior to and during a flood (Figure 4: lesson 1,2,3):

- high water levels > dike breaches > flooding water > effects for inhabitants

We assume that understanding flood risk depends on different types of mental representations. First, mental representations of water levels and the land surface on both sides of the dike, as well as height differences in geographic spaces that are too large to perceive at once, must be combined. Therefore, field observations combined with mental maps are necessary. Furthermore, imagining low probability events with higher water levels and stronger winds than usual is a requisite. Moreover, tagging historical flood information to local situations around dikes is needed. Finally, dike failure mechanisms that are presented on a draft must be tagged to dikes in the surroundings in order to elicit mental simulations of dike breaches. We suppose that virtual flood simulations tailored to the local situation as well as dike breaches in a 3D-setting may contribute to this understanding.

In order to prevent students from emotion-focused coping by emphasizing unilaterally the threats and effects of flooding, an important part of the content is related to hazard adjustments (Figure 4: lesson 4,5,6, and 7). These adjustments deal with measures concerning prevention, mitigation, and emergency preparedness, by the water boards and the inhabitants themselves. For the inhabitants it is necessary to know what they can expect from the water board with respect to prevention and emergency measures in order to appraise their own coping response.

The learning outcomes of each lesson are presented in appendix 2. As the order of the lessons follow the chain of successive events prior and during a flood, each lesson builds on the previous lesson. In addition, the successive lessons are experienced as a whole through the overlap between the student-directed parts. Figure 4 also shows how the stepwise process (Figure 2) and the two types of information processing (Figure 3) are incorporated in the successive lessons. The cyclic process of information processing underlies the formation of knowledge and understanding as well as beliefs and intentions.
Serious games and flood simulation. Serious games and interactive simulations offer the opportunity to prompt both experiential and analytical information processing. Squire and Jenkins (2003, p. 8) made clear that “games are imaginary worlds, hypothetical spaces where players can test ideas and experience their consequences.” In this way games and simulations stimulate imagination and curiosity. But above all, the two modes of information processing are involved. According to Taatgen (1999) people can use two different learning strategies when playing a game. The experiential or search strategy is characterized by looking for cues in the digital environment, reacting on feedback and trial and error. This will result in intuitive knowledge that people find difficult to verbalize. As soon as the search strategy fails, the reflective strategy will be used. This strategy is about analyzing, comprehending, and memorizing consciously and takes more time and is much more demanding. Squire and Jenkins (2003) argued that learning occurs when the game or simulation is alternated with other activities. Furthermore, they state that challenging games urge people to discuss the strategies with others, which is an important aspect in reflecting on the learning itself.

3-D game levee. In the 3D-game Levee Patroller (Figure 4, lesson 1), students had to put themselves in the role of a levee patroller. In a virtual environment, students had to look for various types of weak spots in the dike during a period of high water. The weak spots had to be classified according to a list of dike failure mechanisms. In case they performed the task insufficiently, a virtual dike breach occurred. Playing this game will increase students’ involvement and makes dike failure conceivable.

2-D Flood simulation. Based on information of the regional water board, an interactive digital flood simulation that was useful for students (Figure 4, lesson 2) was developed by the first author. The regional water board played an important role in making available the digital flood simulations. The global design convinced them of the potential success of the use of the simulations. This simulation had a regional map of the school surroundings as a starting point and enables students to create dike breaches at various spots along the dikes in their own surroundings. Subsequently, the effects of the particular dike breach (inundation area, inundation depth, casualties, and costs) are shown and students analyze the effects.

Societal discourse. By giving students the task to question their relatives and friends about flood risk perception and preparedness (Figure 4, lesson 3), we intended to create a situation in which they get
| Stages of the design process | Research questions | Participants | Strength | Weaknesses | Opportunities | Threats |
|-----------------------------|--------------------|--------------|----------|------------|--------------|---------|
| Global design               | 2                  | ▼            | 3         | -the way 2D-simulation is interwoven in the curriculum | -not enough attention to affective goals | -start with evoking affect | -the possibility to adapt the professional flood simulation into a 2D-flood simulation that is usable for students |
| Adaptations                 |                    |              | Evaluation by geography educators (5) and geography educationists (4) | -attribution of pedagogical methods | -too little account of differences between teacher- and student-directed learning activities |                      | |
| Adaptations                 | First draft of teaching material | ▼            | 4         | -3D-game was added to the first lesson | >5 different group projects with respect to preparedness and damage mitigation were added (students chose one) | >fieldwork was relocated to a later stage | |
| Adaptations                 | Second draft of teaching material | ▼            | Try-out in school | -instructive of 2D-simulation were adapted | >teacher guidelines with respect to discussing the outcomes of the 2D-simulation were adapted | >reflection tasks at the end of various parts were added | |
| Adaptations                 | Definitive product (teaching material) | ▼            | 5         | -students are challenged by 3D-game and 2D-simulation | -instruction 2D-simulation is unclear | -starting with fieldwork could be more motivating | -teachers of 50 minutes are not long enough | |

Figure 5. SWOT analyses in relation to research questions 3, 4, and 5.
into conversation. In this way, students will be urged to verbalize and explain what they have experienced already. Furthermore, in the conversation that arises students will have to react and reflect on the topic. This societal discourse is very important in the shaping of their opinion and beliefs.

Fieldwork. The fieldwork assignment (Figure 4, lesson 4) consists of closed-ended observations of a small part of a dike in the surroundings. By observing the dike and encouraging students to assess the strength of the dike on site, we assume that students are in the position to tag elements such as dikes, ditches, and water levels with flood-related images and mental simulations, which they experienced during the lessons prior to the fieldwork. These associations between experiences, elements in the surroundings, and flood risk, should make it possible to pick up from memory flood-related and affect-laden images more easily, thus making the information personally relevant and understandable.

Group-project. In contrast to the fieldwork assignment that has a closed style, the group projects are more open. The group-projects (Figure 4, lessons 5, 6 and 7) are problem-oriented around hazard adjustments by water boards and the people themselves. Students can choose different projects of which the enquiry questions are fixed. The way students gather the information and make a presentation is more or less open-ended and the students are encouraged to describe their opinion and beliefs about the various topics. In this way students are involved in the topic, which becomes more meaningful to them. In this group project students are urged to combine the topics of the previous lessons, therefore various learning activities such as making associations, reacting to each other, analyzing, verbalizing, and reflecting play an important role.

Description of the design process and the design principles

In this section we describe the way the authors used the iterations or stages to evaluate the design principles as well as the manner in which the participants’ evaluations of the intermediate products were used. In the course of the successive stages of the design process, the authors questioned which design principles best described the functions and characteristics of the flood-risk education program (research question 2). The first set of three design principles, motivation, systematic processing, interaction with the surroundings, originated from stage 1. During the stages 2, 3, and 4 the tentative design principles evolved and were sharpened. In hindsight, after an iterative process as described in the stages 1 to 4, we conclude that a program that aims at changing flood-risk perceptions and preparedness intentions should start with intrusive information and extending knowledge and understanding. By evoking both experiential and analytical information processing, the appraisal of the threat of flooding and the coping strategies will be initiated. This could lead to belief change. Therefore, the functions and characteristics of the flood-risk education program could best be described with the design principles affect, availability, and blended learning, as described previously.

The design process consisted of five stages. During stages 2, 3, and 4, the design products of the preceding stage were evaluated by experts in a focus-group discussion. In this study the first four stages of the process are described starting from the research questions presented in Figure 1. The development of the global design and the first and second draft of the teaching and learning material took place during stages 1, 2, 3, and 4. Stage 2 focused on the soundness of the design ideas and coincides with the phase of “alpha testing” as described by McKenney and Reeves (2012). Stage 3 and 4 had to do with the viability of the teaching and learning material. These stages coincide with the phase of “beta testing” (McKenney & Reeves, 2012).

The participants’ comments are categorized in a SWOT-format as listed in Figure 5. The consistency of the curricular components (research question 3), the variety of pedagogical methods, the problem-oriented character, and the 2D-simulation were judged positively. Suggestions were made about a more prominent role of affect and the more student-directed parts concerning coping strategies. This was addressed in the first draft of the teaching material. The expected practicality and effectiveness of the teaching material (research question 4) were studied during stage 3. Core issues of geography teachers’ comments are listed in Figure 5. In general, geography teachers assessed the material as
inspiring and stimulating because of the pedagogical variety, the use of a 3D-game and 2D-flood simulation, and the focus on the surroundings. Their main concerns had to do with the explicitness of the 2D-flood simulation, the possibility for students to reflect, and the feasibility with respect to required time. These comments were addressed in the second draft.

Stage 4 consisted of a pilot in school. Two geography teachers used the teaching material during their lessons with two groups of 15-year-old students at pre-university education level (VWO) and senior general secondary level (HAVO). The teachers found the material very useful (Figure 5). They were extremely enthusiastic about the 2D-flood simulation. The main problem concerned the instruction prior to the 2D-flood simulation and the time for reflection afterward. Furthermore, the motivation for the fieldwork assignment was less than expected because of conflicts with obligations of other school subjects at the same time. This clarifies that coordinating with the school organization plays an important role while carrying out such an intervention with pedagogical methods that substitute as homework.

Conclusions

This study reports on the development and formative evaluation of a flood-risk education program in the Netherlands, based on an educational design research approach. The objective of this study lies in describing both the design product and design process. Furthermore, this study aims for design principles, theoretical notions about the functions and characteristics of the program that evolves during the design process.

The challenge of this study lies in designing a flood-risk education program that contributes to improving 15-year-old students’ personal flood-risk perceptions and flood-preparedness intentions. Based on risk communication research, we assume that students’ thinking about flood risk should be modeled as a stepwise process that consists of knowledge and understanding, awareness and perception, and preparedness intentions. In order to overcome various obstacles in this stepwise process, we have made use of learning theory and understandings about information processing that proved to be complementary. Learning processes must be modeled in such a way that accommodative learning occurs. This can be achieved when learning activities consist of both experiential and analytical information processing.

In the flood-risk education program, students are confronted with intrusive flood-risk information about the local situation that should arouse moderate levels of fear. In this way, students are prompted to process flood-risk information analytically, without causing panic and emotion-focused coping. By incorporating serious games, simulations, fieldwork, and discourse, students should experience different aspects of flood risk in the surroundings. This enables students to tag elements in surroundings with flood-risk information and affect-laden imagery. By emphasizing both the threat of flooding and coping measures, students should get a balanced picture of flood risk.

During the development of the flood-risk education program that consists of teaching and learning material, experts evaluated the intermediate products formatively. Consistency, practicality, and expected effectiveness were evaluated successively. Although experts evaluated the alternation of pedagogical methods and flood-risk related topics positively, they were critical about achieving the affective goals; therefore, reflection assignments and group-projects were incorporated. Finally, the pilot showed that geography teachers were convinced that exposing students to intrusive information, in combination with attention to coping strategies, could bring about belief change without causing panic. In hindsight it can be mentioned that the regional water board as well as the Dutch Ministry of Infrastructure and Environment were so pleased with the program that they sponsored an online version (www.overstromingsrisicocatlas.nl).

In the course of the development of the flood-risk education program, the design principles affect, availability, and blended learning evolved. For the time being, we assume these principles are the main characteristics of this program that should contribute to realistic flood-risk perceptions as well as preparedness intentions. As soon as the intervention has taken place, it will be clear whether these principles will last.
**Limitations**

The main research question of this study is about determining the characteristics of a flood-risk education program that contributes to improving flood-risk perceptions of 15-year-old students in flood-prone areas. Within this framework, we must take into account the limitations of this study. These limitations involve the character of this study and the position of the flood-risk education program in the geography curriculum.

First, the formative evaluation could have benefited from incorporating students’ evaluations. Furthermore, as this study focuses on the design process of the flood-risk education program, a summative evaluation of the program (phase 5 in Figure 2) is not part of this study. In order to judge the effectiveness of the program and finally answer the main research question, it is necessary to test the flood-risk education program experimentally in schools in the targeted area. This experiment, consisting of a pre-test/posttest design, will be the only way to determine the effect of the flood-risk education program on beliefs with respect to flood risk.

Both Harries (2008); Heems and Kothuis (2012) made clear that risk perceptions and attitudes toward preparedness are deeply embedded in more fundamental beliefs that are prevalent in society. Perceptions and attitudes should be influenced by notions about the man-nature relationship, the manipulability of the environment, and the distribution of responsibilities in society. In order to change these fundamental notions, it might be possible that a flood-risk education program of seven lessons would be too short. Possibly more fundamental changes in the geography curriculum of junior secondary education are necessary.

**Note**

1. This material consists of a course book with student assignments, a teacher’s guide with power points, an online serious game, an online simulation program.

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Appendix A

Global design

| Rationale | With respect to the topic: Despite the fact that the government indicates that 100% safety cannot be provided with regard to flooding and it is imperative that people know what to do at the time of a flood, risk perception among students is low.
 | With respect to learning: Knowledge construction takes place through personal and social processes whereby the existing cognitive structure and motivation play an important role. A variety of learning strategies is necessary. Students' own surroundings are central.

| Aims and objectives | Learning outcomes |
|---|---|
| -Students are able to mention what waters in their surroundings can be threatening. -Students are able to explain under what circumstances high water causes a threat. -Students are able to mention the dikes and dunes in their surroundings that contribute to their safety. -Students are able to explain what mechanisms cause the breakthrough in a dike or dune. -Students are able to explain how the spatial distribution of flooding water is influenced by height differences, the position of the (possible) breakthrough in the dike and the location of minor dikes. -Students are able to describe the height of flooding water in familiar places like their home and school. -Students are able to describe what the effects of a flood in their surroundings are on daily life of themselves and their relatives. -Students are able to describe what activities the water board undertakes in order to maintain and reinforce the dikes. -Students are able to mention what parts of the dikes and dunes in their surroundings do not meet the standards. -Students are able to mention the extent to which the authorities are able to support the inhabitants during a flood. -In case of a flood in their surroundings, students are able to argue whether they had better evacuate to another place or flee to the upper floor.

| Student roles | -attending instruction lessons interspersed with making assignments -analyzing digital flood simulations -conducting fieldwork in their surroundings -entering into dialogue with the social environment -constructing and presenting a presentation

| Teacher roles | -Instruction/ inspiring -tutoring -giving them free rein -assessing

| Materials and resources | -Coursebook with assignments -Teacherguide and powerpoints -Digital flood simulations -The social environment (Parents, relatives, friends)

| Grouping | -Individual and in groups

| Location | -In the classroom -At home -In the field

| Assessment | Test and report

Global design, part 2 - Succession of lessons

| Lesson 1 | Introduction about flooding in the school surroundings
 | Lesson 2 | Flood simulation and map analysis
 | Homework | Fieldwork concerning dikes in the surroundings
 | Lesson 3 | Working out fieldwork: PowerPoint presentation with photos and maps
 | Lesson 4 | Water management by the water boards: prevention, mitigation and disaster preparedness
 | Homework | Surveying family and friends
 | Lesson 5 | Analysis and interpretation of survey results
 | Lesson 6 | Presentations about survey results and group discussion
## Appendix B

### Flood-risk education program with respect to West-Friesland

| Content per lesson | Learning outcomes | Cognitive | Affective |
|--------------------|-------------------|-----------|----------|
| **1** Dikes and dike breaches in the province of North-Holland and the region West-Friesland | Causes (high water + dike failure mechanisms) | -Students are able to describe with what frequency flooding in their surroundings took place in the past. |-Students experience how weaknesses in the dike are related to dike failure |
| **2** The effects of flooding in the province of North-Holland and the region West-Friesland | Effects (inundation area and depth + casualties + costs) | -Students are able to describe the height of flooding water in familiar places like their home and school. | -Students experience the effects of flooding in their surroundings. |
| **3** Water management in the province of North-Holland | Authorities (prevention, mitigation, disaster preparedness) | -Students are able to describe the water board in their surroundings deals with flood prevention and water levels in polders. | -Students believe that the consequences of flooding in their surroundings can be devastating. |
| **4** Flood preparedness and mitigation measures in the surroundings | Self (prevention, mitigation, disaster preparedness) | -Students are able to search for and analyze information with respect to flood prevention, mitigation and preparedness. | -Students are able to cooperate on a flood related topic. |
| **5** | -Students are able to evaluate information in order to use it in a presentation. | -Students are able to create a presentation which persuades others of the necessity to pay attention to flood preparedness. |
| **6** | -Students are able to evaluate information in order to use it in a presentation. | -Students believe self efficacy in case of a flood is necessary in order to enlarge the chance of survival. |