RISK LITERACY: FIRST STEPS IN PRIMARY SCHOOL

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Data about risks in health care or investments are usually presented in terms of proportions, probabilities and percentages. Research shows that risk communication can be misleading as these representation formats are sometimes hard to understand. Thus a first level of 'Risk Literacy' should be achieved as early as possible. With cognitive psychologists of the Harding Center for Risk Literacy I developed a school intervention on 'Risk' for fourth graders. The intervention contains elements of proportional reasoning, loss/benefit trade-offs, conditional probabilities as well as dealing with relative and absolute risks. Prior studies have shown that hands-on materials in form of colored tinker-cubes in combination with 'natural frequencies' and iconic representations constitute a good approach. The intervention was tested and evaluated by means of a pretest, a posttest and a follow-up test. The results indicate that students benefited by the intervention as test performances increased significantly.

DECISIONS UNDER UNCERTAINTY

Informed decision making in times of uncertainty has become a crucial skill in modern society. In the last decades there had been a shift to more options and opportunities in several domains of human life like transportation, nutrition, investments and, above all, safety and health. Should I take the prescribed pill? Does it makes sense to buy nutritional supplements in order to lead a "healthier" life? Which are the real chances and risks when deciding about screenings or about certain kinds of surgery?

Questions about health-related risks or financial investments are often complex and their consequences are far-reaching. The basis for decision-making should always be data in form of numbers and statistics rather than emotions and beliefs. Knowing numbers, graphs and scales thus becomes all the more important considering that professionals like medical doctors themselves may fail to understand risk-related statistics, as has been empirically established during the last 30 years (Gigerenzer, 2013). Professionals may often be in conflict of interests; juristic and economic reasons determine patient treatments (Gigerenzer & Gray, 2011). That risk-related statistics often fail their aim of informing both patients and public at large which is mainly due to bad representation formats the mind cannot digest (Gigerenzer, 2013; Kurz-Milcke et al., 2011). Information about chances and risks of different options is much better processed when its communication is based on frequency formats combined with iconic representations (Brase, 2008; Spiegelhalter, Pearson & Short, 2011; Schapira, Nattinger, & McHorney, 2001). Findings of cognitive psychology reveal that these formats are natural because they are adapted to the evolution and socialization in the development of human cognition (Kurz-Milcke et al., 2011). Frequency formats are also suitable for young learners in math classrooms and they are a natural preparation for ratios and probabilities.

RISK ILLITERACY AND INNUMERACY

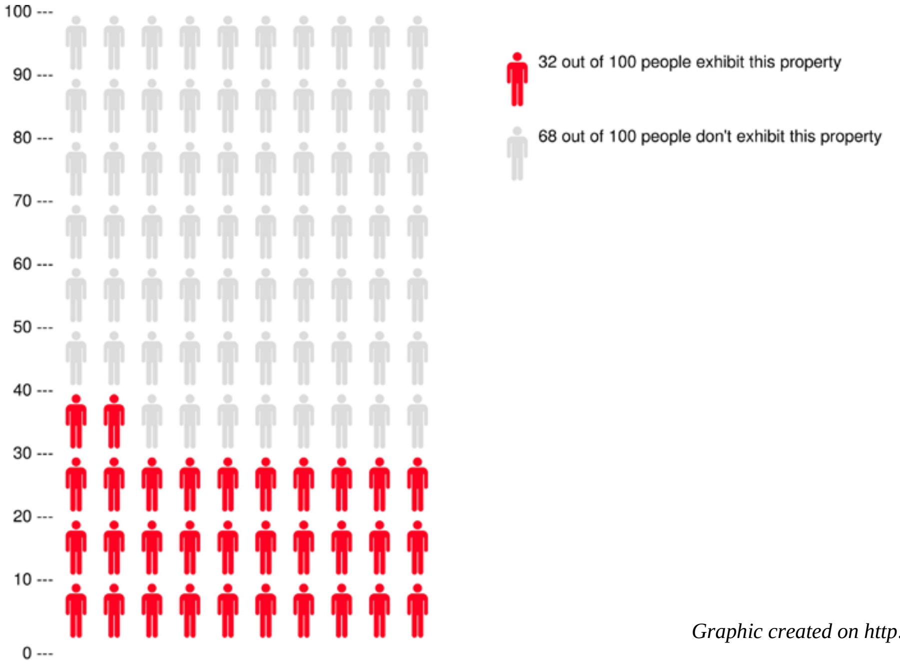
Cognitive psychologists of the Harding Center in Berlin have dealt with specific questions concerning human decisions in times of risk and uncertainty. One of their main findings is that people´s risk perception seldom follows pre-established norms. For instance high risks are often underestimated whereas low risks may cause great fear, overconcern and protective measures. Innumeracy and misconceptions on probability hamper people's correct estimates and interpretations of risks (Gigerenzer, 2013; Kahneman & Tversky, 1984). Galesic and Garcia-Retamero (2010), for instance, tested American and German participants with regard to their numeracy skills in risk-related situations. The following questions were two of their items. *(rate of right solutions in brackets for US and German participants).*

- "Which of the following numbers represents the biggest risk of getting a disease? 1 in 100, 1 in 1000, or 1 in 10?" *(71.8% / 75.3%)*

In K. Makar, B. de Sousa, & R. Gould (Eds.), *Sustainability in statistics education. Proceedings of the Ninth International Conference on Teaching Statistics (ICOTS9, July, 2014), Flagstaff, Arizona, USA.* Voorburg, The Netherlands: International Statistical Institute. iase-web.org

- "If person A's chance of getting a disease is 1 in 100 in 10 years and person B's risk is double that of A, what is B's risk?" *(54.5% / 57.3%)*

Almost a quarter of adults gave a wrong answer to the first question, and even about half of the adults gave a wrong answer to the second question. Although people often have problems understanding probabilistic information, the usual way to communicate it today still is by means of ratios and probabilities. Research shows that people's performance in probabilistic tasks improves when information is presented in frequency formats (Gigerenzer, 2013; Gaissmaier & Gigerenzer, 2008; Schapira et al., 2001): *32 out of 100* is much easier to understand than *32%*. Performances improve even more when graphical and analog representations in form of icon arrays are added to the presentation (Brase, 2008; Gaissmaier & Gigerenzer, 2008; Gresh, 2012). These representation formats use icons for each individual in a population with a certain attribute. This one-to-one match between individuals and icons invites to identification as it is directly seen as part of the whole population (Martignon & Kurz-Milcke, 2006).



Graphic created on http://www.iconarray.com/

Figure 1. Icon Array to represent a sub population

FOSTERING RISK LITERACY IN PRIMARY SCHOOL

First efforts to implement Risk Literacy in primary school have shown satisfying results (Martignon & Krauss, 2009). In the view of Gerd Gigerenzer, director of the Harding Center for Risk Literacy, young children should early become familiar with the construct Risk Literacy, which comprises knowledge both in financial and medical issues and competencies in dealing with information presented by (digital) media (Gigerenzer, 2013). Young children can (learn to) understand risk and elementary probabilities if they are introduced in a playful way. An early fostering of risk competencies can contribute to the development of grown-ups who deal wisely with their lives' uncertainties.

In my study I focus on basic mathematical competencies, which bundled together constitute a first component of risk literacy: these are *proportions*, *conditional probabilities* and *expected values*. These mathematical concepts appear to be essential for modeling and quantifying risk (Martignon & Krauss, 2009; Latten et al., 2011; Schiller & Kuntze, 2012). As these concepts are usually taught in higher grades and fourth graders in Germany are not yet familiar to ratios and fractions, probabilities are translated into proportions: conditional probabilities become conditional proportions and simple expected values become proportions multiplied with a quantified resource (see section on *Method*). Another basic competency for Risk Literacy is pondering between different alternatives (Latten et al., 2011). Choosing between alternatives means having a good sense of their probabilities and the gains/losses associated with them; young children can acquire these competencies at an elementary level and later on acquire the mathematical tools of probabilities and expected values to handle more general and subtle cases. In fact, recent studies on children's understanding of probability confirm early intuitions of expected values (Schlottmann & Wilkening, 2011). The third basic mathematical element of Risk Literacy is the field of conditional probabilities and bayesian reasoning, which is fundamental for risk estimates (especially in medical issues). Expressed in frequency formats, conditional probabilities can be introduced in elementary school by means hands-on, concrete, encoded representations using, for instance tinkercubes (see section on *Method*).

Preliminary studies have shown that this bundle of basic mathematical concepts consisting of proportions, expected values and conditional probabilities can successfully be conveyed to primary school children (Latten et al., 2011; Martignon & Krauss, 2009). The main aim of my study is to collect empirical evidence students' improvement in content knowledge of these probability concepts through the intervention. The following sections are devoted to the phases that constitute the study.

Research Questions

- Which basic intuitions do children aged 8 to 10 have about pre-concepts of probability and decision making under uncertainty before they attend a corresponding learning unit?
- Does the intervention affect these intuitions and pre-concepts and foster them?
- Does the intervention affect content knowledge of proportional reasoning, expected values and conditional probabilities in a different way?

Sample

The sample consisted of 244 fourth graders between the age of 8 and 12. They were from six different elementary schools in the wider area of Ludwigsburg, Baden-Württemberg, Germany. The enquiry period lasted from December 2012 till July 2013. The sample was divided into a treatment group (8 classes) and a control group (4 classes). The classes of the treatment group attended a learning unit of different elements of Risk Literacy, whereas the classes of the control group had regular math classes.

Materials and Organization of the Unit

The intervention in form of a learning unit consisted of four single math lessons. In each lesson the students worked with colored tinker-cubes and urns, which not only served for the analog representation of different frequencies, but also as a tool for random experiments. The first lesson covered comparisons of simple proportions in risk-related contexts. The lesson consisted of different tasks like the following: "*My uncle has 30 lettuce plants in his garden. 10 of them have been bitten by snails. My aunt has 100 lettuce plants, from which 20 have been bitten by the snails. In which garden is the risk for planting lettuce higher*?"

In the second lesson the students were confronted with a trade-off situation in which they had to weigh up two different options. One option was associated with a small but certain gain and one with an uncertain high gain. "Either you take 10 chocolate bars for sure or you choose the option to draw at random out of a box (10 times). If you draw a yellow cube, you win 4 chocolate bars. If you draw a red cube, you get nothing." The students had to weigh up pros and cons for the two different options. After this discussion the students sat together in pairs and simulated the risky situation by running the random experiment. At the end of the lesson the results of the different pairs were collected and finally the students realized that the riskier option of this trade-off is associated with the higher gain on average.

The third lesson purported questions about relative and absolute *risk reduction*. These terms were not used, but the students learned what is meant by "reduced by half". We discussed this in classroom with similar examples as the following: "'*4 out of 12'* children have caries. When all of them brush their teeth regularly, the risk of having caries is reduced by *half*. Assume that all children brush their teeth. How many of them do now have caries?" We discussed explicitly the difference between the risk reduction ‘*4 out of 12’* into ‘*2 out of 12’* and the reduction of the proportion ‘*4 out of 12’* into ‘*2 out of 6’*.

The fourth and last lesson comprised questions about conditional probabilities and Bayesian inference which were simulated and modelled with the children:

> *“In a school yard there are 2 girls – one with long hair and one with short hair. There are also 8 boys – 2 with long hair and 6 with short hair. Assuming I tell you I talked with one of these children and the child had long hair. Would you bet it was a girl?”*

Figure 2. Bayesian task

This is a typical Bayesian task, where the base rate (prior probability) of ‘*girl’* is ‘*2 out of 10’*. Having long hair is new evidence on the situation so that one has to check whether it influences the prior. Indeed knowing that the child I talked with had long hair, modifies the chances of the child being a girl from ‘*2 out of 10’* to ‘*1 out of 3’*. The probability ‘*1 out of 3’* is the posterior probability of ‘*girl’* which is far larger than the prior. Yet you would not bet, I talked with a girl because the probability of ‘*girl’* among ‘*children with long hair’* is less than less than 50%. Children can learn to blue cubes for ‘*boy*’ and red cubes for ‘*girl*’, ‘*long hair*’ with ‘*white*’ and ‘*short hair*’ with black.

Evaluation Tools

The test instrument was a math test which consisted of different stochastic tasks. Each of the students of the sample was tested three times: at the beginning of the enquiry period (pretest), one week later (posttest) and once again three month later (follow-up test). The 25 test items contained open and closed questions about proportions, frequencies and probabilities embedded into the context *risk* and *uncertainty*. At the beginning the students were introduced to the testing procedure. Then they had approximately 30 minutes time to do the test. The learning unit started the day after and took the next four math lessons, each of them 45 minutes long. I taught the classes by myself in order to ensure that the lessons in each of the eight classes were similar. After the accomplished learning unit, all of the students had to do a posttest. Three months later, each student of the sample was tested again, in order to get information about long-term-effects of the intervention. Between posttest and follow-up test there was no further training.

The students’ performance in the posttest was operationalized as an indicator for the students’ understanding of the treated concepts. The tests contained only few iconic representations and thus led the students to mentally imagine iconic or enactive representations if necessary. Information about age, gender and grades from the last reports in mathematics was collected in order to control for the independent variables in the multiple regression analysis. The most important variable in my study was the test condition ‘belonging to the treatment group or not’.

Results

The results of the analysis of the pretests agree with results by Fischbein et al. and other researchers who proved, in contrast to Piaget’s early findings, that children aged 8 to 10 have basic pre-concepts of probability and decision making under uncertainty (1^{st} research question) (Fischbein et al., 1970). The descriptive statistics of the pretest performances reveal that almost all students had intuitions concerning simple comparisons of probabilities. Students showed also basic intuitions for dealing with conditional probabilities and very simple expected values. They had difficulties with less elementary comparisons of proportions and more complex tasks with conditional probabilities and expected values.

The result of the multiple regression analysis confirmed the effectiveness of the intervention (2^{nd} research question). The adjusted R^2 of .577 indicates that more than 57 % of the variability in the performance in the posttest is predicted by the following three variables:

Table 1. Regression weights of the predictors in the multiple regression analysis

pretest score	$\beta_{pre} = .483;$	$p < .000$
test condition	$\beta_{cond} = .424;$	$p < .000$
grade in Mathematics	$\beta_{maths} = -.281;$	$p < .000$

In comparison to the variables *pretest score*, *test condition* and *grade in Mathematics* the variables *age* and *gender* had no significant β coefficients. The general mathematics competencies (*grade in Mathematics*) as well as being part of the treatment group (*test condition*) and pre-knowledge of the trained concepts (*pretest score*) are good predictors for the posttest results.

A multiple regression analysis was also carried out for the prediction of the follow-up test. It turned out that the same variables showed significant β coefficients: $\beta_{pre} = .407, p < .000;$ $\beta_{cond} = .209, p < .000;$ $\beta_{maths} = -.318; p < .000$. The adjusted R^2 of .459 indicates that more than 45 % of the variability in the performance in the follow-up test is predicted by the variables *pretest*, *test condition* and *grade in Mathematics*. The results indicate that there are long-term effects of the intervention. All in all, my results show that three month after the intervention students who were part of the treatment group achieved significantly better follow-up test scores compared to students of the control group. The next step will be to look at the development of specific content knowledge conveyed by the unit (3rd research question). Further analysis of the tests will reveal in which areas the intervention had the highest or the lowest impact.

DISCUSSION AND CONCLUSION

The results of the analysis showed significant effects of the variable *test condition* which indicated that students who attended the learning unit got significantly higher post- and follow-up test scores than students who attained unspecific math lessons. This confirmed the assumption that young learners' understanding of risk can be fostered by playful activities with hands-on materials and good iconic representations. Of course, it is possible to imagine that computer supported interventions may achieve even better results. The shortness of my intervention – 4 lessons – was due to my awareness that teachers are usually reluctant to give away too many hours for experiments. Should the contents of my study ever become part of the curriculum in fourth grade, the required time would be necessarily extended.

The study shows that *Risk and decision making under uncertainty* can be a prevailing, exciting and meaningful topic at the end of primary school. Current ways of teaching data and chance in elementary school classes are often characterized by descriptive statistics ("What is your favorite animal?") or gambling situations with dice, spinners and lottery boxes. Relating those learning approaches to risk would mean embedding them into a real-life context.

The students had much fun performing random experiments, predicting, reflecting and discussing risk-related situations. The effectiveness of the treatment was statistically demonstrated and the students' learning increase of the concepts is sustainable. As Gigerenzer has repeatedly pointed out elementary probability concepts should be taught in an informal and heuristic manner at an early stage. This can help children to grow up, prepared for the uncertainties of the modern technological world where the understanding of statistical information becomes more and more indispensable.

ACKNOWLEDGEMENT

Christoph Till is a member of the "Cooperative Research Training Group" of the University of Education, Ludwigsburg, and the University of Tübingen, which is supported by the Ministry of Science, Research and the Arts in Baden-Württemberg.

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