STUDENTS' BELIEFS ABOUT THE BENEFIT OF STATISTICAL KNOWLEDGE WHEN PERCEIVING INFORMATION THROUGH DAILY MEDIA

Alexandra Sturm[1] and Andreas Eichler[2]
[1]Institute of Mathematics Education, University of Education Freiburg, Freiburg, Germany
[2]Institute of Mathematics, University Kassel, Kassel, Germany
sturmfr@ph-freiburg.de, eichler@mathematik.uni-kassel.de

One general aim of developing students' statistical literacy is to achieve students' critical stance referring to statistically-based decision making in modern society reported in daily media like newspapers or TV. However, research shows that adults are predominately struggling with statistical information proposed by daily media. Therefore, we focus on the relation between students' statistical knowledge and their beliefs. Our research approach consists of developing and conducting an intervention study aiming to connect statistical knowledge with the application of this knowledge. With mixed methods (tests & interviews), we investigate the development of both students' statistical knowledge and students' beliefs about the benefit of statistical knowledge when perceiving information through daily media. In our report, we outline the development of the intervention, the method of our investigation and first results.

SETTING THE FIELD

"Citizens who cannot properly interpret quantitative data are, in this day and age, functionally illiterate" (MSEB-NRC, 1990, p. 8).

The ability to properly interpret quantitative data and, thus, to properly interpret statistical data in daily life is described in statistics education research as statistical literacy (Gal, 2004), which is described by Wallman (1993, p. 1) as "the ability to understand and critically evaluate statistical results that permeate daily life, coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions". Developing statistical literacy is a challenge of teaching statistics in schools addressed across countries all over the world (e.g. Watson, 1997; Shaughnessy, 2007). The benefit of achieving students' statistical literacy is not restricted to schools or any specific profession, but is understood more globally as a competence of adults or, respectively, as a prerequisite for being a critical and informed citizen and an intelligent consumer (NCTM, 2000).

The definition of Wallman (1993) comprises a distinction of statistical knowledge and attitudes or rather beliefs towards statistics as two different, but connected parts of statistical literacy. Thus, the basis of statistical literacy is not only the ability to critically evaluate statistical results that is based on statistical knowledge. In fact, further "the willingness to invest mental effort" (Gal., 2004, p. 69), and respectively, an individual's belief that to invest mental effort has a benefit in a specific statistically-laden situation is part of statistical literacy. Although an educational goal might be to improve both knowledge and beliefs by an educational intervention, research shows that this is not necessarily the case (e.g. Schau & Emmioglu, 2012). In an own study (Eichler, 2008), we also find a discrepancy between an increase of statistical knowledge and an improvement of statistical beliefs. Since the knowledge of 20 students of upper secondary schools increased considerably in a statistics course lasting half a year, after the course most of them neither indicated that statistics is important for decision making in society nor indicated that statistics might have a benefit for their own life. Thus, achieving statistical knowledge does not necessarily seem sufficient to appreciate the benefit of statistics "in public and private, professional and personal decisions" (Wallman, ibid.).

In our research we primarily focus on the development of knowledge-based and dispositional elements of statistical literacy. Concerning the dispositional elements, our main focus is on beliefs referring to students' perception of the benefit of statistics for both society and their own life. For this, we developed an intervention aiming to improve both knowledge-based and dispositional elements of statistical literacy of different students, i.e. students in school and students at university of different faculties. In this report, we firstly outline the main constructs of our research by describing a model of statistical literacy and by specifying the construct of beliefs. Further, we focus on the specific statistical topic that we address in our intervention, i.e. theorem of

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

Bayes, and we outline exemplarily a statistically-laden situation and visualization of this situation. Afterwards, we discuss methods aiming to investigate knowledge and beliefs as a part of statistical literacy. Finally, we provide some results of a pilot study.

A MODEL OF STATISTICAL LITERACY

Of the different existing models of statistical literacy (Shaughnessy, 2007), we primarily use the model of Gal (2004, p. 51) that is shown in Figure 1.

Knowledge elements of statistical literacy	Dispositional elements of statistical literacy
Literacy skills Statistical knowledge Mathematical knowledge Context knowledge Critical questions	Beliefs and Attitudes Critical stance

Fig 1: Aspects of statistical literacy

Like Wallman (1993), Gal distinguishes knowledge elements and dispositional elements as constituent parts of the construct of statistical literacy. Three of the knowledge elements of statistical literacy seem to be non-mathematical and even non-statistical, i.e. the ability to perceive information through an oral or written text (literacy skills), the ability to perceive a certain context in which data are produced (context knowledge) and the ability to be aware of possible manipulations in reports that are based on statistics (critical questions). However, although these three elements include non-mathematical aspects, it is widely accepted that statistical data are numbers in a context (Moore, 1990) and, thus, integrating statistical and contextual aspects is a main competence in thinking statistically (Wild & Pfannkuch, 1999). It is further possible to distinguish mathematical and statistical knowledge by defining certain mathematical procedures as parts of a specific statistical knowledge (Gal, 2004). However, we avoid this distinction in our research approach and subsume mathematical knowledge to statistical knowledge.

To discuss the dispositional elements of Gal's model of statistical literacy, we briefly outline our understanding of the constructs of beliefs and of attitudes.

BELIEFS AND ATTITUDES AS ELEMENTS OF STATISTICAL LITERACY

Both beliefs and attitudes are understood as parts of mathematics-related affect (Hannula, 2012). We understand the term beliefs as an individual's personal conviction concerning a specific subject, which shapes an individual's ways of both receiving information about a subject and acting in a specific situation (Pajares, 1992). By contrast, attitudes could be defined as "affective responses that involve positive or negative feelings of moderate intensity and reasonable stability" (McLeod, 1992, p. 581). Thus, we distinguish beliefs as representing the cognitive part of mathematics-related affect, and attitudes as representing the affective part (cf. Hannula, 2012). For example, if a student says that statistics provides a tool to understand decision making in society, he indicates an individual conviction and, thus, a belief. I f a learner says that he likes statistics, he indicates a favor (or disfavor) towards an object und, thus, indicates an attitude towards statistics (cf. Eagly & Chaiken, 1998).

Referring to the first example, it is, for our purposes, worthwhile to further distinguish beliefs towards the world and beliefs towards the self, which partly refer to the theory of self-efficacy or rather outcome expectations (Bandura, 1977; Usher & Pajares, 2009). Thus, a student could believe that statistics provides a benefit for the society in a global sense one the one hand, and could further evaluate his ability to use statistics in his own life on the other. In our research, we restricted the focus to beliefs and do not focus on attitudes.

PROMOTING KNOWLEDGE ELEMENTS AND DISPOSITIONAL ELEMENTS

To investigate a possible improvement of knowledge elements and dispositional elements of statistical literacy we defined three requirements referring to the topic of an intervention. Firstly, the subject should emphasize the benefit of statistics for both society and at most potentially for an individual's life. We understand the existence of a certain topic in daily media as an indicator for this characteristic mentioned above, namely an emphasis of a potentially benefit of statistics for society. Secondly, the topic should not be a standard-issue. Indeed, research results give evidence concerning students' difficulties of interpreting elementary statistical concepts like a bar graph, which is considerably present in daily media (Watson, 1997; Shaughnessy, 2007). However, for our purposes we looked for a topic that, potentially, is unfamiliar for students and, particularly, is unprecedented for adults (students at university) and, thus, provide a new insight about the benefit of statistics. Closely connected with the last requirement, we defined a subject to be appropriate if there exist elaborated strategies of designing a potentially effective intervention with regard to an improvement of statistical knowledge.

Taking into account the three requirements, we decided to choose Bayes' theorem as the subject-matter for the intervention. This topic is existent in daily media (fig. 2) and emphasizes a benefit of statistics for both an individual and the society. Further, according to the research of Sedlmeier and Gigerenzer (2001), Bayes' theorem or Bayesian thinking is not common-place. Finally, research results give evidence for the efficiency of two different forms of visualization in short-term interventions, i.e. a tree with natural frequencies (e.g. Sedlmeier & Gigerenzer, 2001) and the unit square (Bea, 1995).

From: SpiegelOnline, 2012/07/04

HIV-rapid-test for a home usage: An effective less-than-ideal- solution
From Irene Berres
The Food and Drug Administration (FDA) permits a HIV-rapid-test for a home usage. The simplified method could yield an increased number of persons that using a HIV-test. However, missing guidance includes risk ...

Fig 2: Headline in a German online-newspaper (translated)

The intervention is developed for about three hours and is based on problems that could be solved by using Bayes' theorem. The problems themselves are adapted or directly taken from newspapers and mainly refer to a diagnosis of diseases like HIV, breast cancer or, in a broader sense, doping. In each problems, a base rate of a disease or an infection (P(D)) and conditional probabilities representing the correct-positive rate (P(+|D): probability of a positive test result given a disease) and representing the false-positive rate (P(+|nD): probability of a positive test result given no disease) have to be arranged according to Bayes' theorem to compute the probability of disease given a positive test P(D|+).

The research of Sedlmeier and Gigerenzer (2001) give evidence that adults without a training in Bayesian thinking mostly fail to give correct estimations of P(D|+). However their research also shows that representing the situation based on a tree diagram with natural frequencies (fig. 3, left side) increases the rate of correct estimations. Similarly, Bea (1995) yield this result based on the unit square (figure 3; right side). Both representations are shown in Figure 3 with fictitious probabilities.

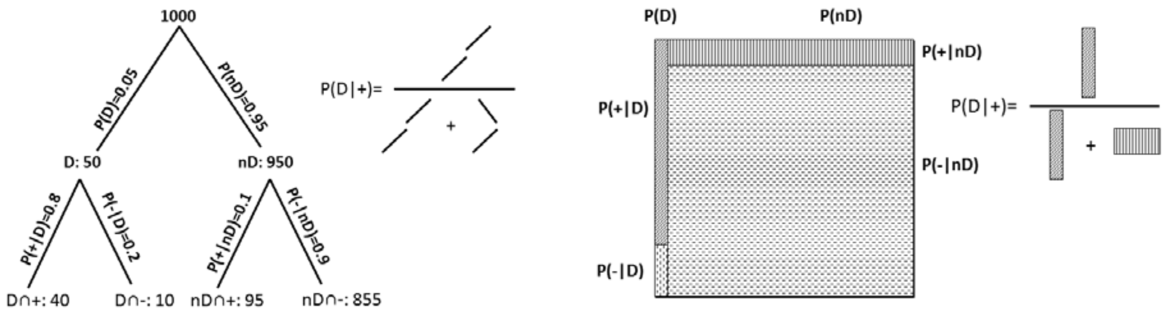

Fig 3: Tree with natural frequencies and unit square representing a Bayesian situation

Both visualizations are used in the intervention to explore statistical situations that are based on Bayes' theorem.

METHOD

Since this paper concerns an ongoing study, we firstly outline the method of the main study. Afterwards we indicate those parts of the method that we used in a pilot study and, discuss corresponding first results in the next paragraph.

The sample in the main study consists of four subsamples of university students. The first sample comprises 60 students without a focus on mathematics (students of German philology), 60 students of mathematics education, and 60 students that potentially apply mathematics (students of health education). A further sample consists of 60 students at school (grade 11). Each subsample is divided in two groups by random. One of the groups uses the tree diagram with natural frequencies, whereas the other group uses the unit square in the intervention.

We use a pre-post-test design. In both, pre-test and post-test, we address elements of knowledge and beliefs as segments of statistical literacy, partly using elements of existing scales. With regard to knowledge elements, we ask the students:

- for estimations for Bayesian situations that we outlined above given the relevant values as percentages. For these we expect a low performance before the intervention and a high performance after the intervention (see Sedlmeier & Gigerenzer, 2001). We subsume the results in this part of the test to both statistical and mathematical knowledge (cf. Gal, 2004).
- for explanations of relevant information given in the task ("Indicate the percentage of those persons who will get a positive test result given that these persons are infected"). We subsume results in this part of the test to the ability to recognize information of a written text correctly (literacy skills and context knowledge; cf. Gal, 2004).

We further ask the students about several dispositional elements, i.e.:

- about their beliefs towards mathematics using a questionnaire of Grigutsch et al. (1998). The questionnaire consists of clusters of beliefs towards mathematics, e.g. application oriented beliefs ("Most parts of mathematics could be applied in reality") or a so called schema-oriented beliefs ("Mathematics comprises applying rules, facts and procedures"). In contrast to the international discussion (cf. Moore & Cobb, 2000), in the German context, statistics is understood as part of mathematics. Thus, we expect that preferred beliefs with regard to mathematics are closely connected to beliefs concerning the benefit of statistics.
- about their beliefs towards the benefit of statistics for the society ("statistics provides a tool to understand decision making in society"), and the students' beliefs towards the benefit for their own life ("statistics knowledge will help me in my own life"). These items were influenced from items of the questionnaire of Grigutsch et al. (1998) and the SATS scale (Schau et al., 1995).

In a first piloting phase, we used further scales referring to the students' interest in mathematics as part of the construct of actual motivation (Lipowsky et al., 2005) and referring to the self-concept and anxiety concerning mathematics (Fennema & Sherman, 1976). In this first piloting phase, we restrict the focus on the scales aiming to measure the dispositional elements of statistical literacy. Our specific interest was, if the scales we used are appropriate to measure a construct. A further interest was to investigate the characteristics of the different constructs if students without a focus on mathematics (pedagogy students) are regarded.

RESULTS OF THE PILOT STUDY

All the scales that we used show an appropriate reliability; the lowest value of Cronbach's α is 0.71 for the 6 items referring to anxiety and α is 0.73 for the 5 items referring to the students' interest in mathematics. The other scales show greater values for α, mostly above 0.85.

The distributions referring to the different constructs seem to reveal a group profile of students without a focus on mathematics.

Thus, these students primarily understand mathematics as a subject-matter with an arbitrary strength (formalist beliefs) and something that necessitates remembering rules and procedures to gain one exact solution (schema-oriented beliefs). In contrast these students hold beliefs in a significantly lower degree that mathematics is also a tool to describe the world and something that represents a process of inventing or, if school mathematics is regarded, of reinventing mathematical concepts.

Further, the students value the benefit of statistics for society and for their own life very similarly compared to the statements representing application-oriented beliefs towards mathematics. The correlation coefficient between the two scales is about 0.7 ($p < 0.01$). Thus it seems that these students value the benefit of mathematics for solving real problems similarly to the related benefit of statistics.

The findings referring to the other scales show expected results concerning the mentioned group profile of students without a focus on mathematics. Thus, the averages referring to the scales representing self-confidence are the lowest in all scales. In contrast, the average referring to mathematics anxiety is high. The scales of both constructs show a high (negative) correlation.

DISCUSSION AND CONCLUSION

We begin with the aim of our pilot study that, of course, does not address our main questions at the moment. However, the aim of our research programme is to develop an intervention to improve both elements of statistical literacy, i.e. knowledge elements and dispositional elements. Before the intervention, we strongly expect a low statistical knowledge referring to the subject-matter we selected, i.e. Bayes' theorem and Bayesian thinking (Sedlmeier & Gigerenzer, 2001). In contrast, it was a crucial preliminary question, whether there exists a certain space to improve the dispositional elements of statistical literacy or whether the students' beliefs about the benefit of statistics are rated highly before the intervention. Thus, we expected that the students without a focus on mathematics do not value mathematics at all, but, however, it was ex ante not clear, which beliefs towards mathematics are central for these students.

The pilot study yields several aspects for a further development of our method. For example, the results imply to reduce our questionnaire by restricting it to one of the strongly correlated scales referring to self-efficacy or anxiety. A further reduction is possible referring to the beliefs scales concerning mathematics since these scales also show a high reliability for lesser items. Reducing the questionnaire considerably referring these aspects, it would be possible to meliorate the questionnaire referring to a more precise distinction of beliefs referring to the benefit of statistics for society and, respectively, for a student's own life, which seems to be a crucial distinction.

On the basis of these improvements of the method to measure the main constructs, we will test our intervention in a further pilot study, which will be conducted in summer 2014. In this pilot we will further triangulate quantitative instruments with qualitative instruments, i.e. the analysis of interviews with some students of our sample. The final step consists of implementing the main study described in the method section that will be conducted in autumn 2014 and will include both students at university and school students. Firstly, we expect different profiles of knowledge and, particularly, beliefs in the different groups of university students that in turn will differ from the beliefs of school students. However, we primarily expect an improvement of both knowledge elements and dispositional elements of statistical literacy by specifically including those problems in the intervention that are a possible target of being statistically literate.

REFERENCES

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84(2),* 191-215.

Bea, W. (1995). *Stochastisches Denken (Stochastical reasoning)*. Frankfurt a.M.: Lang.

Eagly, A. H., & Chaiken, S. (1998). Attitude structure and function. In D. T. Gilbert, S. T. Fisk, & G. Lindsey (Eds.), *Handbook of social psychology* (pp. 269–322). New York: McGowan-Hill.

Eichler, A. (2008). Teachers' classroom practice in statistics courses and students' learning. In C. Batanero, G. Burrill, C. Reading & A. Rossman (Eds.), *Joint ICMI/IASE Study: Teaching Statistics in School Mathematics. Challenges for Teaching and Teacher Education. Proceedings of the ICMI Study 18 and 2008 IASE Round Table Conference*. Monterrey: ICMI and IASE. Online: www.stat.auckland.ac.nz/~iase/publicatons

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman Mathematics Attitude Scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *Journal for Research in Mathematics Education, 7*(5), 324-326.

Gal, I. (2004). Statistical literacy: Meanings, components, responsibilities. In D. Ben-Zvi & J. Garfield (Eds.), *The challenge of developing statistical literacy, reasoning and thinking* (pp. 47-78). Dordrecht, The Netherlands: Kluwer.

Grigutsch, S., Raatz, U., & Törner, G. (1998). Einstellungen gegenüber Mathematik bei Mathematiklehrern. *Journal für Mathematikdidaktik 19, 1*, 3-45.

Hannula, M. S. (2012). Exploring new dimensions of mathematics-related affect: embodied and social theories. *Research in Mathematics Education 14(2)*, S. 137–161.

Lipowsky, F., Rakoczy, K., Buff, A., & Klieme, E. (2005). Dokumentation der Erhebungs- und Auswertungsinstrumente zur schweizerisch-deutschen Videostudie. *Unterrichtsqualität, Lernverhalten und mathematisches Verständnis*. *Materialien zur Bildungsforschung,* vol. 13. Frankfurt am Main: DIPF.

Moore, D. (1990). Uncertainty. In L. Steen (Ed.), *On the shoulders of giants: New approaches to Numeracy* (pp. 95-137). Washington, D.C.: National Academy Press.

Moore, D. S. & Cobb, G. W. (2000). Statistics and mathematics: Tension and cooperation. *American Mathematical Monthly, 107(7)*, 615-630.

Mathematical Science Education Board & National Research council (MSEB-NRC) (Eds.) (1990). *Reshaping school mathematics. A philosophy and framework for curriculum*. Washington, D. C.: National Academy Press.

National Council of Teachers of Mathematics (NCTM) (2000). *Principles and standards for school mathematics*. Reston, VA.: National Council of Teachers of Mathematics.

Pajares, F. M. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62(3)*, 307–332.

Schau, C., Stevens, J., Dauphinee, T. L., & Del Vecchio, A. (1995). The development and validation of the Survey of Attitudes Toward Statistics. *Educational and Psychological Measurement, 55*, 868-875.

Schau, C., & Emmioglu, E. (2012). Do introductory statistics courses in the United States improve students' attitudes? *Statistics Education Research Journal, 11*(2), 86-94.

Sedlmeier, P., & Gigerenzer, G. (2001). Teaching Bayesian reasoning in less than two hours. *Journal of Experimental Psychology: General, 130*(3), 380-400.

Shaughnessy, J. M. (2007). Research on statistics learning and reasoning. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 957–1010). Reston, VA: National Council of Teachers of Mathematics (NCTM).

Usher, E. L., & Pajares, F. (2009). Sources of self-efficacy in mathematics: A validation study. *Contemporary Educational Psychology, 34*, 89-101.

Wallman, K. K. (1993). Enhancing statistical literacy: Enriching our society. *Journal of the American Statistical Association, 88*(421), 1-8.

Watson, J. (1997). Assessing statistical literacy through the use of media surveys. In I. Gal & J. Garfield (Eds.), *The assessment challenge in statistics education* (pp. 107-122). Amsterdam: ISI.

Wild, C., & Pfannkuch, M. (1999). Statistical thinking in empirical enquiry. *International Statistical Review, 67(3)*, 223-248.