# THE PROFESSIONAL KNOWLEDGE OF GERMAN SECONDARY SCHOOL TEACHERS ABOUT DESCRIPTIVE STATISTICS

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*For many years, (descriptive) statistics had an inferior standing in schools worldwide. However, in recent years, a considerable shift from probability to statistics is apparent with regard to National Standards for Mathematics. Nevertheless, studies about teachers' professional knowledge in this new domain are scarce, particularly in Germany, although it is verifiable that the teachers' knowledge has an impact on their classroom practice and also on students' learning. Therefore, a main focus of the research presented here is to generate a questionnaire to survey teachers' professional knowledge in the domain of descriptive statistics. The theoretical basis is on the one hand Ball's model of professional knowledge and the concept of 'statistical literacy' on the other hand. Thus, the theoretical background and its realization in the test instrument itself are presented and discussed.*

## INTRODUCTION

"Descriptive Statistics – a neglected topic at school?" – This was the title of a German journal concerning mathematics and its teaching in July 1997. In its introductory article (Kütting 1997), the omnipresence of data collection, data evaluation and predictions in public discussions is underlined and with it the necessity of conveying basic knowledge in descriptive statistics at school. The insufficient recognition of the somehow unloved topic at school as well as in teacher education is underlined.

Statistics is an important but nevertheless often disregarded skill area even "[…] the teachers generally have […] little knowledge about statistics" (Batanero et al. 2011, p. 12). One reason could be that (descriptive) statistics was not taught intensely to that teacher generation at school or university. Accordingly, they are not sufficiently competent in the content themselves. Another reason could be that teachers may know enough about statistics, but that they are not able to deliver the knowledge to their students adequately. Thus, there are two crucial questions for the research project in which German secondary school teachers' content knowledge and their pedagogical content knowledge in the field of descriptive statistics will be surveyed: (1) To which extent do teachers possess knowledge about descriptive statistics? (2) Are teachers capable to convey their knowledge to their students in an appropriate manner?

In the following, the theoretical background and parts of the specifically developed test instrument in the context of the research project are presented.

## THEORETICAL BACKGROUND

### *National Standards*

In recent years, a change concerning the importance of statistics is apparent. In the first instance, new K-12 curricular programs with "ambitious goals for statistics education" (Ben-Zvi & Garfield 2004, p. 5) were implemented in Australia (1991) and New Zealand (1992), followed by Great Britain (1999) and the USA (2000). Subsequent to those other countries, the shift to a more data driven mathematical education took place in Germany. Related skills are tested in the national final examinations to underline their relevance. 'Data and Chance', as one of five central topics in the German National Standards, comprises that students "evaluate diagrams and tables of data collections, plan surveys, collect data systematically and list it in tables as well as display it in diagrams (also using suitable devices, e.g. software), interpret data with the help of statistical measures, reflect and assess arguments which are based on a data analysis, describe coincidences in everyday situations and determine probabilities in random experiments." (KMK 2004). Thus 'Data and Chance' encompasses statistics and probability, whereat this project concentrates on descriptive statistics as the essential component to work with data.

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*Teachers' Professional Knowledge*

Studying teachers' professional knowledge is a topic that gained importance in recent years. Hill et al. (2008, p. 496) conclude that "there is a powerful relationship between what a teacher knows, how she knows it, and what she can do in the context of instruction". The understanding of teachers' professional knowledge in this project focuses on the refinement of Shulman's well-known categories by Loewenberg Ball et al. (2008). They distinguish between the two main categories "Subject Matter Knowledge (SMK)" (with its sub-categories 'Common Content Knowledge' –CCK– and 'Specialized Content Knowledge' –SCK–) and "Pedagogical Content Knowledge (PCK)" (with its sub-categories 'Knowledge of Content and Students' –KCS–, 'Knowledge of Content and Teaching' –KCT– and 'Knowledge of Curriculum') (ibid. p.5ff.). In this project, the focus is firstly on the subject matter knowledge, including both types, the mathematical knowledge known by a well-educated adult and the specialized mathematical knowledge explicitly necessary for the teaching domain and secondly on the pedagogical content knowledge, covering KCS (e.g. knowing about students' difficulties or typical mistakes) as well as KCT (i.e. knowing how to explain or represent a topic to the students). However, it is important to note that the boundaries of those categories are not always clear cut and can be blurred (ibid. p.11).

The emphasis of this project is on finding answers to the following questions: How well-grounded is the teachers' knowledge about descriptive statistics actually? How comprehensible can teachers explain technical terms to their students, how well do they recognize mistakes and react appropriately to them? In this paper, the basic approach for finding answers to these questions is described and some supporting items are shown.

*Statistical Literacy*

The concept of 'statistical literacy' serves as a basis for the test instrument and concrete topics are chosen according to the German curricular standards for secondary schools. "Statistical literacy is the ability to understand and evaluate critically statistical results that permeate our daily lives – coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions." (Wallman 1993, p.1).

Watson established a three-tiered framework for statistical literacy for students whereat every tier can be sub-divided again according to the level of understanding in solving each task (Watson & Callingham 2003, p.7):

- 1st tier: The understanding of basic statistical terminology
- 2nd tier: The understanding of terminology when it appears in social contexts
- 3rd tier: The ability to question claims that are made in context without proper statistical justification

Although Watson conducted studies with students, the established hierarchy can be regarded as fundamental and transferred to studies with teachers, too.

IMPLEMENTATION

The aim is to develop a questionnaire for secondary school mathematics teachers in Germany as a test instrument to examine teachers' professional knowledge in the field of descriptive statistics. In the main part of the pen-and-paper-questionnaire, 28 SMK- and 18 PCK-items will be examined either via multiple-choice- or open-ended-questions. Whenever possible, a connection between the SMK-item and a suitable PCK-task will be created. Furthermore, teachers will be asked for biographical data such as age, years of service and joined teacher trainings in descriptive statistics. Moreover, attitudes and a critical stance will be examined briefly with some items for interest, self-concept and self-efficacy. With regard to the inferior role these items play in the study, they will not be further discussed in this paper due to the limited space.

*Test Instrument*

Each item is first of all categorized according to its content. The concrete topics are taken from the curriculum for secondary schools regarding the domain of 'Data and Chance'. For this project, only topics relevant for data are chosen and clustered as follows:

- Absolute and relative frequency
- Statistical measures of center and spread (e.g. mean, median, range)

- Graphics (tables, bar chart, boxplot, pie-charts…)
- Critical analysis of data

Especially among items of the last three topics, teachers' understanding of variation is surveyed (i.e. for example by comparing two box plots or paying attention to outliers). Moreover, informal inferential reasoning is necessary, e.g. for one item in which the German rate of birth – which is 1.36– has to be explained. In the following, some exemplary items are presented.

*SMK-Items*

The SMK-items are categorized according to their content and Watson's three-stage hierarchy. Figure 1 deals with graphics and can be allotted to Watson's third tier. Teachers, as well as well-educated adults, should be able to find out several mistakes in this pie-chart (e.g. summing up all percentages equals 128.5%, not 100% as it should; although 'Others' make up for 61.2%, the part in the pie-chart is less than 50%).

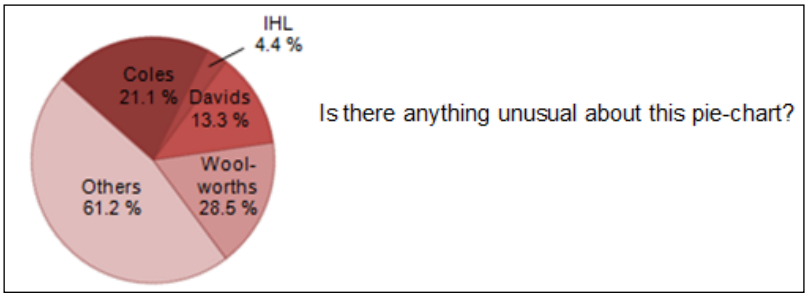


Figure 1. Example for a CCK-item [on the basis of Watson (2006, p. 80)]

Figure 2 is an example for a SCK-item dealing with graphics as well as statistical measures and can be classified as part of the first tier of Watson's hierarchy. Teachers need a more specific and detailed knowledge here than one would expect from a well-educated adult with regard to constructing a box plot.

The following temperatures (already arranged in order of size) were metered in the city of Bielefeld in May 2013.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 11 | 12 | 13 | 13 | 14 | 15 | 15 | 15 | 16 | 17 | 17 | 17 |
| 17 | 19 | 20 | 20 | 22 | 22 | 22 | 22 | 22 | 23 | 23 | 23 | 24 |
| 24 | 25 | 25 | 27 | 31 | | | | | | | [in °C] | |

source: *wetterausbielefeld.de*

Please present those temperatures in a box plot.

Figure 2. Example for a SCK-item

*PCK-Items*

The item shown in Figure 3 deals with statistical measures (in this case the mean). In order to solve this task, teachers should know about typical mistakes students make (e.g. just paying attention to the numbers, but forgetting to think about the time span covered while driving).

Ms. Schmidt drives 200 kilometers with her car. She travels the first 100 kilometers with a speed of 50 km/h, the second 100 kilometers with 100 km/h.
What is the average speed with which Ms. Schmidt travels?

Here you see one student's answer.
Explain the thoughts that could have led her to that solution.

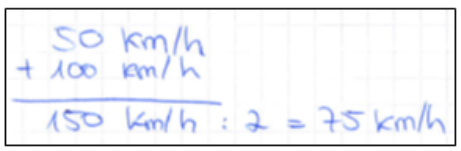


Figure 3. Example for a KCS-item

The fourth figure shows an item to survey teachers' knowledge about content and teaching. Teachers have to know how to explain specific statistical terms to their students in a way that is appropriate and realistic for them. Once again, the topic is statistical measures (in this case the median).

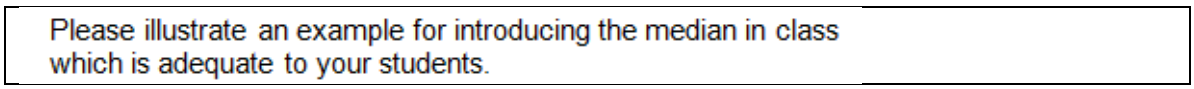


Figure 4. Example for a KCT-item

The answers to the open-ended questions will be categorized according to their level of response in the style of the SOLO-taxonomy by Biggs (1979).

*Sample*

In a field study the questionnaire has been conducted among 41 teacher students at the University of Bielefeld to detect difficulties in understanding the tasks and to get a first insight in solving them. It shows that many items are answered on a superficial level, not paying attention to connections between different representations of data etc. Moreover, there were problems dealing with the PCK-items. The reason for this could be the students' missing teaching practice. Thus, the pilot study will take place in spring 2014 with approximately 30 in-service-teachers. The main study following up will be conducted with at least 100 mathematics teachers randomly chosen from diverse secondary schools in a region of North Rhine-Westphalia.

## OUTLOOK

After the pilot study in spring 2014 and the subsequent verification of the test instrument, the main study will take place in autumn 2014. Results of the pilot study will be documented for the conference in July. The adjacent analysis of the results of the main study could lead to further training arrangements for in-service-teachers or to an adjusting of the contents in mathematics, especially regarding statistics, for pre-service teachers at universities.

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