WHAT KIND OF CONTENT REMAINS IN MEMORY AFTER A CONTINUOUS PROFESSIONAL DEVELOPMENT FOR STATISTICS? RESULTS OF AN INTERVIEW STUDY

Thomas Wassong
Paderborn University, Germany
wassong@math.upb.de

Designing and implementing professional developments (PDs) is one of the preferred ways for spreading the innovations from university to schools. For increasing the number of reached teachers so-called multipliers are needed, but these multipliers need also to be qualified for the PDs. This paper deals with the design and implementation of PDs for multipliers. The research question for this paper is about what kind of content remains in memory of participants 2–3 months after a PD for statistics and what can be inferred for the presentation of the content during a PD for statistics. We will report about the results of an interview study that was implemented in 2013 2–3 months after ending the PD for multipliers in statistics in Germany.

INTRODUCTION

Following Hattie (2009, p. 119) the professional development of teachers is one aspect that has a desired effect on the achievement on students. This raises the question what are the relevant factors for good professional developments (PDs). The German Centre for Mathematics Teacher Education (Deutsches Zentrum für Lehrerbildung Mathematik, DZLM) was founded in 2011 with the aim to investigate these factors and the establishment of these factors in Germany for mathematics. In addition to PDs for teachers, the DZLM is primarily concerned with the qualification of multipliers. Multipliers are persons who are qualified to implement PDs. Often these are teachers who, in addition to their role as teachers, also take on the role of trainers. The question is how to qualify these multipliers. What content and skills do the multipliers need? Which concepts of further education and which methodological aspects should the multipliers know and be able to apply?

In their meta-analysis of 72 studies on further education in mathematics, Timperley et al. (2007) identified as one central factor, among other things: Positive learning effects for students show up when the professional development stimulates teachers to reflect on and adapt their previously used arguments and ideas with regard to the subject matter and also the learning of students (Timperley et al. 2007, p. 196). Therefore, the question arises how these processes can be stimulated for each topic of a professional development. This paper attempts to identify various content aspects of statistics, in particular of descriptive statistics taught at lower secondary level in Germany.

First, it is necessary to reflect briefly on the particular challenges that arise in a PD on a content-oriented topic in general and descriptive statistics in particular.

- Due to the differences between schools, it is virtually impossible to implement a PD on a content-oriented topic in such a way that all participants can implement the content of the course in their classroom at the same time.
- Descriptive statistics is relatively new in the German curriculum. This means, in particular, that a large number of teachers did not have this subject in their classes as students.
- At the same time, descriptive statistics has only recently established itself as a central topic in the content of teacher education. Thus, most of the teachers did not deal with this topic during their study-time.
- In dealing with the new topic, teachers have developed different strategies for adopting the new content. This has resulted in a great heterogeneity of content knowledge and pedagogical content knowledge.

In summary, it can be said that the previous knowledge of the teachers is heterogeneous. Therefore, it is more likely that PD participants will start with little prior knowledge. At the same time, it can be assumed that the basic concepts exist in form of calculation rules and definitions for individual concepts, but that the link between the concepts is as incomplete as the pedagogical knowledge of the concepts. The preliminary surveys of the participants in the concrete qualification confirm these assumptions, at least for the group of this study (Wassong, 2017, p. 279).

In M. A. Sorto, A. White, & L. Guyot (Eds.), *Looking back, looking forward. Proceedings of the Tenth International Conference on Teaching Statistics (ICOTS10, July, 2018), Kyoto, Japan.* Voorburg, The Netherlands: International Statistical Institute. iase-web.org

DESIGNING A CONTINUOUS PROFESSIONAL DEVELOPMENT FOR STATISTICS IN LOWER SECONDARY SCHOOLS

In the school year 2012/2013, the DZLM conducted a qualification for multipliers in the federal state of North Rhine-Westphalia. This qualification covered the entire school year and was divided into two parts. In the first half of the year, the focus was on descriptive statistics, while in the second half of the year the focus was on the development of process-oriented competence. For this paper we concentrate on the first six months.

Thirteen multipliers took part in the qualification. In addition to their duties as teachers, these multipliers were also responsible for continuing education in their district. Apart from one exception, the participants taught in secondary and comprehensive schools. This means, that the participants mainly taught students who will not finish their schooling with an A-level.

The qualification was organized in a blended learning scenario. Fortnightly meetings were held in which the participants worked together. In the weeks in between, two-hour webinars were held. Between September 2012 and February 2013 there were a total of 7 attendance dates and 6 webinars.

The goals of the course were (1) developing competencies for teaching statistics in a comprehensive sense including the use of digital tools and (2) developing competencies for teaching these competencies in professional development courses for other mathematics teachers. Therefore, we formulated seven design principles as objectives of the qualification: (I) To develop a vision of data analysis in mathematics lessons (see Burrill & Biehler, 2011), (II) to use digital tools in the learning process, (III) to develop the structure and reasoning in the context of data analysis, (IV) to address participants in each of their three roles (as learner, as teacher and as multiplier), (V) to strengthen further education didactic competences and (VI) to accompany the implementation into practice.

The theoretical background was provided by a model of teacher knowledge (Wassong & Biehler, 2010) and a topic structure concerning teaching statistics. The model of teacher knowledge consists of four knowledge facets (i) *common and practice oriented content knowledge*, which deals with the mathematical and statistical background of data analysis in school and preparing the content for school. (ii) C*ontent and pedagogical knowledge of curriculum* consists on the one hand of the knowledge about the development of data analysis for all grades in school and on the other hand of the knowledge and experiences concerning different teaching materials and their classroom use. (iii) *Pedagogical knowledge of teaching and learning* focuses on the concrete planning of lessons and reflects the development of students' understanding. (iv) *Common and pedagogical technological content knowledge* deals with the use of technology for data analysis in school and consists on the one hand of skills in the usage of digital tools and knowledge about the strengths and weaknesses of different tools and on the other hand with the concrete use of the tools in classroom and its influence of the students' understanding. Besides the model of teacher knowledge a content structure of six topics has been developed. (a) *Introduction to data-analysis with digital tools*, where the participants were introduced to the basic usage of digital tools for doing data-analysis, e. g. Fathom and Excel. (b) *Data: Where from and what for?*, which dealt with the nature of data that are useful in classroom, like real data vs. artificial data, different types of variables and their representation in different contexts, and good examples of data sets for classroom activity. (c) *Representing, summarizing, and interpreting data*, which also included the discussion about developing competencies with relevant data distribution graphs (bar graphs, histograms, box plots, e. g. Friel, Curcio, & Bright, 2001). (d) *Trends and relationships in data*, where we discussed the comparison of two distributions with histograms, box-plots and numerical summaries. Fitting functions to data was a second theme here, particularly from the perspective of signal and noise. (e) *Dealing critical with statistics and data in the media (statistical literacy)*, which dealt with making decision under uncertainty and with realistic data used in political discussions and for political decision making. (f) *Statistical projects and presentations with digital media*, where competencies developed in the other topics were put together to develop overall competencies in the sense of the PPDAC-circle (Wild & Pfannkuch, 1999) and an example of a statistical project.

METHODS, DATA & PARTICIPANTS

After the end of the CPD a study was performed with the goal to evaluate the CPD. The study consists of in-depth interviews with each of the participants. The interviews were divided into two parts. The first part discussed the objectives, expectations and motivation of the various actors (teacher educator and participants). The second part focused on the sustainability of the CPD in terms of both their role as teachers and their role as trainers. This paper deals with the second part, the sustainability in relation to the role as teachers. For this part of the interview, the participants were asked to answer several questions concerning several content topics. The questions asked were conceived in the sense of a retrospective self-report (e.g. Lam, 2003):

- How did you deal with this topic in your lessons before the CPD?
- What did you learn during the CPD? What is still missing for you?
- How would you design your lessons on this topic now, after the CPD?

The content areas discussed covered all aspects of descriptive statistics on lower secondary level: Data, averages, graphical representations, especially box plots, distributions, comparison of distributions, data and functions, conditional probabilities as well as statistical projects including the use of technology.

As described in the introduction, this paper investigates which processes of reflection and adaptation among teachers can take place in the context of a PD on descriptive statistics in upper secondary education. In particular, it deals with the question which content triggers the processes on teachers. In order to better understand how diverse these processes can be and to identify the common aspects of the processes, two teachers are described in detail here in the frame of a case analysis (Mason, 2002). The aim of the description is, on the one hand, to show the range and heterogeneity of possible processes and, on the other hand, to show the heterogeneity between the participants as discussed in the introduction. The two cases (Alexandra and Bodo) were selected because they have different prerequisites, e.g. mathematics teacher vs. non-subject-specific, young moderator vs. experienced moderator.

The first teacher we will call Alexandra. She has more than 10 years of professional experience as a mathematics teacher at a secondary modern school and is chairing the Mathematics Conference at her school. She took on the role of a multiplier less than two years ago and sees herself as a relatively inexperienced multiplier. Until the beginning of the qualification, she has conducted three PDs on the topics of cooperative learning and individual support through tests. At the time of the preliminary survey, she indicated to only use prepared Excel files as digital tools in mathematics lessons. Other tools such as GeoGebra and Fathom as well as self-created files were not used. When asked about the challenges she sees in her role as a multiplier compared to her role as a teacher, she replied that she felt obliged to keep abreast of current developments in mathematics teaching. She sees it as her task to be an expert in mathematics teaching.

The second teacher we will call Bodo. He has more than 10 years of professional experience as a mathematics teacher at a lower secondary school but has not completed a mathematics course of studies. He has been a multiplier for more than five years. During this time, he has conducted more than 10 PDs on various topics: Activation of students, individual promotion and development of lessons (Green/Klippert). He sees his expertise primarily in supporting schools in their development. With regard to the use of digital tools, he states that Excel and GeoGebra are to be used with self-created files. In response to the question of what challenges he identifies in the role of moderator in comparison to the role of teacher, he emphasizes the special target group of teachers. In comparison to the target group of students, other and special solutions are necessary. In response to the question of what role content-oriented knowledge (as opposed to didactic knowledge) means for him in his role as a multiplier, he points out that comprehensive content-oriented knowledge is necessary for successful further training and that he has to acquire it for each further PD. At the same time, however, he does not claim to be an expert in mathematics teaching.

RESULTS AND DISCUSSION

The first teacher, Alexandra, describes her lessons before CPD with the following words: “So, of course, I also taught a bit as the textbooks are. I have to be self-critical about it. So methodically certainly better than the textbooks, but in terms of content probably already at textbook level, and that is somehow one-dimensional and I would just do that now in a different way.” (The

author does all translations.) Her description shows the one-dimensionality in the different areas: In the fifth grade class, she begins with a mini data collection among the students, which is evaluated by hand with a tally sheet. In later classes, she uses bar charts and pie charts, but also boxplots. Dotplots, histograms and scatterplots did not occur. On the subject of averages, she said "Learning goals [in terms of averages] was: it is in the school's own curriculum, [so] I have to make it." She was not familiar with the concept of distribution until CPD, nor had she used any digital tools until then. However, what she has already used in the classroom was comparing groups using boxplots. "So I have often had two classes in parallel in the past years, so I had two classes in parallel here for four years and now I have two classes in parallel again, and I like to draw two boxplots under the evaluation of the class test. [...] Well, if I look at it that way, […] it is distributed quite differently, then I illustrate that [...] with a boxplot and always found that you can see certain things totally clear on it and that's what tells me about the classes and the outcome of the class test".

After participating in the CPD, she would change the following things in her lessons: With regard to the subject of averages, she would now work out the meaning of arithmetic means and median and emphasize their differences. Up to now it has remained at the level of the calculation of the values: "Of course I can determine a median and calculate arithmetic mean, but I wouldn't have known before in which way these are really useful or where they don't make sense, but today I could imagine discussing this as well".

The above-mentioned one-dimensionality also refers to the questions that are put to the data: "Such simple things as simply to read off […] values, how have things changed, change things over time, or is an offer from a sports club sufficient for certain age groups [....] and I think I'd like to take up more complex questions and just want to establish relationships between data, so I'd be much more open-minded and just watch a lot more, what can I discover."

Alexandra also focuses on digital tools. "[With digital tools] you can take a real dataset and analyze it reasonably and, as I said before, you can ask real questions and really discover things and that's why I think you just need a digital tool for an adequate modern statistics lesson".

The Simpson paradox was the topic that was particularly important to her in the context of the CPD. On a webinar on Conditional Probabilities we reported the case in admission rates at the University of California, Berkeley. In the interview, she cites the example of the (supposedly) misogynistic university, and at the same time she emphasizes the central message of the Simpson paradox: "If you find a connection between two characteristics in a group, it is possible to divide the group into sub-groups in such a way that this relationship is negated. Therefore, other factors must always be taken into account."

The second teacher, Bodo, describes his teaching before the CPD with the following words: "The learning objectives were up to now, I must have the ability in an exam to apply certain techniques. That means I don't have to understand them, I don't have to be able to say that I like them, but I just have to be able to calculate them. This is as flawless as possible, although my wish is always that a child should only pick up the things in such a way that they can really use them, i. e. that they have internalized them. Because that doesn't mean it has to decide and say, "Okay, I better take the mean or the median". With regard to the collection of data, Bodo formulates that he has an affinity for collecting data due to his other subjects (earth science, chemistry) but that he has so far missed the right tools and media to collect "reasonable data". So far he has worked with tally sheets, but was not able to arouse enthusiasm among the students. For the selection of datasets he uses the datasets given in the textbook. He also referred to the textbook on the subject of graphic representations, but at the same time he reveals his dissatisfaction: "Children were always happy, liked to spend hours with drawing diagrams and, conversely they also had the opportunity to read things, but always with a little rumbling in the background, why do I really need it, I would have recognized it with three lines. [...] Well, I can't change the diagrams in the book. I'm just having trouble getting other charts every five minutes." Likewise, the topic boxplots was only of interest to him because of the curriculum specifications.

In the interview, Bodo describes in reference to the learning goals in his stochastic lessons that by participating in the CPD, he has learned new ideas for achieving his intended goals. Here he emphasizes the possibilities to build up a world of perception for the students and to support them with haptic elements. His focus is on the idea that "mathematics is a tool for solving problems". A central example what Bodo calls here is the subject of quartiles. By participating in the CPD, he has

understood what quartiles are and what they mean. On this basis, he can now start comprehension-oriented lessons.

Bodo also sees a further development in the performance of data collection. If the time is available, he plans to carry out data collection as mini-projects. The CPD provides the necessary tools to realize a data collection

The topic of averages is of central importance for Bodo in his further development following the CPD. Due to the different visualizations, which were picked out as a central issue within the CPD, he now has a repertoire of didactic explanatory patterns to explain, for example, what the arithmetic mean means. In concrete terms, he gives the idea of accepting a water basin, which is divided into different subdivisions of equal size. The subdivisions are filled differently. If you now take the different subdivisions out of the basin, the water level becomes level with the arithmetic mean of the original water levels. A second example, according to Bodo, was an interaction in which median and arithmetic mean are plotted to a data series of 10 values. The values of the data series can now be changed and the drawn values change dynamically. The different behavior of the median and arithmetic mean can be experienced by appropriate value changes.

With regard to the use of graphical representations, Bodo recognizes the advantages of using digital tools. “Today, from a different point of view, I say, ‘Yes, well, if I start to work nowadays and see it under the new focus: changing the numbers and seeing the results instantly, it's of course completely different’. Well, I can't change the diagrams in the book. [...] In principle, the point is that we say: ‘We have collected relatively simple data and we are now beginning to think about data, so first of all explain what we see, what we see, where questions might arise and then think about what would change if this and that happened’. So really, I'll say a vitality has been developed. A vitality of stochastic and no longer passivity.”

The results shown above can be interpreted under four aspects. First of all, the results show that individual CPD objectives seem to be fulfilled, at least for Alexandra and Bodo. The goal (I) to develop a vision of data analysis in mathematics lessons is illustrated, among other things, by the statement of Alexandra, who describes her previous stochastic teaching as one-dimensional and tries to include more complex questions based on the suggestions of the CPD. Bodo also expresses such a change, especially with regard to the use of diagrams, in which he takes a new vitality of stochastic for his teaching. Concerning the goal (II) to use digital tools in the learning process, Alexandra emphasizes her view that modern stochastic teaching is not possible without digital tools. Bodo emphasizes the added value of digital tools both in the collection of data and in the dynamic display of diagrams. The third objective (III) to develop the structure and reasoning context of data analysis is shown in the topic of averages. Both teachers stress that they focused only on the calculation of average before attending to the CPD. Through the CPD, however, they have been taught the knowledge of structure and reasoning context on the one hand, and on the other hand, the didactic means of developing the topic of averages in a more sophisticated way.

In addition, the statements by Alexandra and Bodo show that the initially formulated challenges to a CPD on the subject of stochastics confirm this. The statements show that the teachers who have been interviewed were not able to convey the subject of stochastics in this intensity and depth, which was supposed by the teachers for other topics in their teaching. Especially Bodo formulates this explicitly. One reason for this is the lack of prior knowledge that teachers have built up on this subject. In many cases, it is reduced to calculating values. However, the challenge and the demand for modern stochastic teaching are falling by the wayside, as the teachers realize. An example is Bodo, who cannot comprehend the meaning of the (simple) reading of values from diagrams without reading between and beyond the data.

The results also show that teachers adopt the CPD's offers, especially with regard to didactic tools such as visualizations, interactions, applets, explanatory patterns and examples. These are the contents in which the teachers show a lack of knowledge, as described above, in order to be able to achieve the standard of their own teaching (e.g. Bodo's statements on his claim to mathematics teaching). These contents can be identified with the term Special Content Knowledge (SCK; Ball, Thames, & Phelps, 2008). These contents have a double effect: On the one hand, teachers can use these didactic tools to use them in the classroom. On the other hand, it also helps teachers to broaden their own understanding of the content. This side effect, in which teachers are implicitly addressed as learners themselves, is important and must be taken into account.

The results also show another aspect. The textbooks, which are at least used here, do neither meet both the demands of the teacher and the demands of modern stochastic teaching. Independently of each other, the two interviewees formulate that they primarily adhere to the textbook. At the same time, they express a certain dissatisfaction with their lessons and thus also with what the textbook offers them. This is not surprising, however, as textbooks are written by teachers who are in a similar situation as the interviewees. The other teachers interviewed do not express this criticism so clearly.

CONCLUSION AND IMPLICATIONS

The research question pursued in this article deals with the content that leads participants to reflect on their lessons so far. The results presented above and their interpretation show that contents from the area of SCK, i.e. didactic tools such as visualizations, interactions, applets, explanatory patterns and examples, prompt this. It also becomes clear that the prerequisite for this is to be found above all in the lack of matching the teachers' demands on their own teaching and the lessons that are actually carried out. In further PDs on stochastics, it is therefore important to take these contents into account. However, the challenge remains how these contents can be didactically appropriately integrated. It is important to keep an eye on the teacher's primary viewpoint, i.e. the teacher's view of his or her teaching and not to place stochastic expertise in the foreground. The special significance of SCK for participants in a PD as well as for lecturers of a PD (multipliers) has been discussed by Elliott et al. (2009), but without referring specifically to a topic. This article concretizes their results.

REFERENCES

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content Knowledge for Teaching: What makes it special? *Journal of Teacher Education, 59*(5), 389–407.

Burrill, G., & Biehler, R. (2011). Fundamental Statistical Ideas in the School Curriculum and in Training Teachers. In C. Batanero, G. Burrill, & C. Reading (Eds.), *Teaching Statistics in School Mathematics-Challenges for Teaching and Teacher Education: A Joint ICMI/IASE Study* (Vol. 14, pp. 57–69). Dordrecht: Springer Science+Business Media.

Elliott, R., Kazemi, E., Lesseig, K., Mumme, J., Carroll, C., & Kelley-Petersen, M. (2009). Conceptualizing the Work of Leading Mathematical Tasks in Professional Development. *Journal of Teacher Education, 60*, 364–379. http://doi.org/10.1177/0022487109341150

Friel, S. N., Curcio, F. R., & Bright, G. W. (2001). Making sense of graphs: Critical factors influencing comprehension and instructional implications. *Journal for Research in Mathematics Education, 32*(2), 124–158.

Hattie, J. A. C. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London: Routledge.

Lam, T. C. M. (2003). A Comparison of Three Retrospective Self-Reporting Methods of Measuring Change in Instructional Practice. *American Journal of Evaluation, 24*(1), 65–80.

Mason, J. (2002). Qualitative Researching (second edition). London: SAGE Publications Ltd.

Timperley, H. S., Wilson, A., Barrar, H., & Fung, I. (2007). *Teacher Professional Learning and Development. Best Evidence Synthesis Iteration*. Wellington, New Zealand: Ministry of Education. Retrieved from http://educationcounts.edcentre.govt.nz/goto/BES

Wassong, T. (2017). *Datenanalyse in der Sekundarstufe I als Fortbildungsthema. Theoriegeleitete Konzeption und Evaluation einer Multiplikatorenqualifizierung*. Wiesbaden: Springer.

Wassong, T., & Biehler, R. (2010). A Model for Teacher knowledge as a Basis for Online Courses for Professional Development of Statistics Teachers. In C. Reading (Ed.), *Data and context in statistics education: Towards an evidence-based society*. Proceedings of the Eighth International Conference on Teaching of Statistics (pp. 41–46). Voorburg, The Netherlands: IASE. Retrieved from http://icots.net/8/cd/pdfs/invited/ICOTS8_3C1_WASSONG.pdf

Wassong, T., & Biehler, R. (2014). The use of technology in a mentor teacher course in statistics education. 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: IASE. Retrieved from http://icots.info/9/proceedings/pdfs/ICOTS9_3D4_WASSONG.pdf

Wild, C. J., & Pfannkuch, M. (1999). Statistical Thinking in Empirical Enquiry. *International Statistical Review, 67*(3), 223–248.