

THE USE OF TECHNOLOGY IN A MENTOR TEACHER COURSE IN STATISTICS EDUCATION

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In 2012 the two authors of this article planned and implemented a 4-month mentor teacher course. The content of this course concentrated on descriptive statistics and data analysis for 5th to 10th graders in Germany. One central topic of the course was the use of technology like Fathom as a tool for learning and doing statistics: How to use Fathom for the analysis of real data, what are usable tasks for the classroom, how to use Fathom for visualizing properties of mean and median, and how to use online-tools like GoogleDocs for collecting data? In our article we will focus on the technological knowledge for common and pedagogical content aspects: What were the concrete topics, we communicate? Which educational settings did we use? What were the feedback we got from the participants by questionnaires and interviews?

INTRODUCTION

In 2011 the German Center for Mathematics Teacher Education (DZLM, <http://www.dzlm.de>) was founded to design and evaluate continuous professional development courses for teaching mathematics and to develop national standards for continuous professional development of mathematics teachers in Germany (Kramer & Lange, 2014). In this context the two authors planned and implemented a one-year continuous professional development (CPD) for mathematics mentor teachers (MMTs) in the federal state North-Rhine Westphalia in Germany. The participants were experienced mathematics teachers, who were also responsible for the professional development of teachers in their county. The CPD was split into two parts: The first part dealt with statistics in secondary school and spanned over four months. The second part dealt with competence-oriented mathematics teaching in secondary school. For this paper we will concentrate on the first part of the course.

The goals of our course were conveying competences for teaching statistics in a comprehensive sense including the use of digital tools and conveying competencies for teaching these ideas in professional development courses for other mathematics teachers (MT). Thirteen MMTs participated at our part of the CPD. Most of the MMTs had between 2- and 5-years experience as MMT, two MMTs had less than 2-years experience and some between 5- and 10-years experience. Only one MMT had organized a professional development about statistics before.

The course was organized in a blended learning format with 14 meetings. Seven of them were full-day face-to-face meetings and seven were online-meetings realized with the web conferencing platform Adobe Connect, which was a new way of meeting both for participants and trainers. During the CPD we discussed 6 topics concerning data-analysis in secondary school: (a) *Introduction to data-analysis with digital tools*, where the MMTs were introduced to the basic usage of Fathom and Excel for doing data-analysis. (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 to be used in the classroom. (c) *Representing, summarizing, and interpreting data*, which included the discussion about developing competencies with relevant data distribution graphs (bar graphs, histograms, box plots) aiming at higher reading levels in the sense of Friel et al. (2001) (d) *Trends and relationships in data*, where we discussed the comparison of two distributions with histograms, box-plots and numerical summaries. Fitting functions and data was a second theme, particularly from the perspective of signal and noise. (e) *Critical dealing with statistics and data in the media (statistical literacy)*, which dealt with making decision under uncertainty (Wassner et al., 2007) and with real data used in political discussions and for political decision making (Krüger, 2012). (f) *Statistical projects and presentations with digital media*, where competences developed in the other topics were put together to develop overall competences in the sense of the PPDAC-circle (Wild & Pfannkuch, 1999) and a best-practice example of a statistical project (Prömmel & Göckede, 2010).

Each topic was structured in a so-called sandwich-model: A topic was introduced with a talk on a face-to-face meeting. The following online-meeting was used for deepening the topic and the topic was finished up in the face-to-face-meeting afterwards.

Besides working on these topics, the MMTs were asked to work on three overarching tasks: (1) a data-analysis project based on a data set of a questionnaire the MMTs developed during the CPD. The MMTs had to submit a written “statistical project report” as a part of the certificate requirements. (2) A task developing project, where the MMTs were asked to design self-differentiating tasks around a real medium-sized data-set. An exemplary solution of the task together with comments from a didactical perspective had to be submitted. And (3) the design of short (one afternoon) professional development course (SPDC) for other MT in small groups with two to four MMTs, where the MMTs should plan and implement a teacher training in the context of data-analysis in secondary school with a focus on using digital tools.

DESCRIPTION OF THE COURSE CONCERNING THE USE OF TECHNOLOGY

For designing the course we used a model for mathematical teacher knowledge (Wassong & Biehler, 2010) for structuring the topics. This model was guiding the developing of our activities and we used it for identifying gaps in our design of the concrete activities. In summarizing reduction of Wassong and Biehler’s (2010) complex model, we defined four facets of mathematical teacher knowledge that we addressed with our activities: (i) *Common and practice oriented content knowledge*, which deals with the mathematical and statistical background of data analysis in school and with preparing the content for school. (ii) *Content and pedagogical knowledge of curriculum* consists on 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 experience 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.

The facet common and pedagogical technological content knowledge is based on the conceptual papers from Niess (2005) and Mishra and Koehler (2006) and, especially for statistics education, on Lee and Hollebrands (e.g., 2011). This facet deals with two aspects: (1) competencies concerning the use of digital tools as such and (2) competencies concerning the use of the digital tools in classroom settings considering especially the pedagogical aspects of the use. The first aspects includes the knowledge about software and its educational potential concerning data-analysis, especially Excel and Fathom; the competency to choose the appropriate software for a certain objective concerning data-analysis, the knowledge about the limits of Excel and Fathom and about the usage of both concerning data-analysis, the competency to use them for problem solving regarding data-analysis and the competency how the use these tools changes the way of doing data-analysis in school, to reflect these changes and to have an own, founded viewpoint to this change. The second aspect covers the knowledge about how using digital tools like Excel and Fathom changes the way of teaching data-analysis and their objectives and the competency to use different instructional strategies and representations for teaching data-analysis with digital tools, the knowledge of different learning environments and learning material using digital tools that enlarge students' insights concerning data-analysis and the competency to integrate these learning environments in classroom settings, as well as the knowledge about new misconceptions and educational pitfalls that can arise while using Excel and Fathom and the competency to recognize and handle these misconceptions and pitfalls in classroom.

For our course we decided to use both Excel and Fathom as digital tools. Fathom is not widely used in secondary school in Germany, although this digital tool is particularly suited for teaching data-analysis (and also for teaching probability) Biehler et al. (2013) classified Excel as not well suited for teaching data-analysis in school. The analysis of raw data is quite complicated, especially the comparison of distributions, and there is still no easy possibility to plot a box-plot without add-ons. Therefore we developed a set of Excel-Worksheets, which simplify the work with raw data and the comparison of distributions. This includes the comparison of box-plots without

using an add-on. As a third digital tool we used GoogleDocs (now Google Drive) and its feature of generating online questionnaires. The form of the questionnaire can be generated with a special and easy-to-use form-editor and then is available online for the students. The students can fill it out and the data will be directly saved into a spreadsheet, which can be imported into Excel or Fathom.

Between the first and second face-to-face meeting there was a 4-week-period, where we started with the topic Introduction to data-analysis with digital tools. Therefore the MMTs started with the multimedia online tutorial eFathom (Biehler & Hofmann, 2012) to learn the handling of Fathom with first small tasks, replicating the actions shown in the tutorial videos. In the next step we chose two tasks from Biehler et al. (2011) the MMTs had to solve. Biehler et al. (2011) also provide sample solutions for their tasks so the MMTs were able to check their solution. For introducing Excel combined with our data-analysis worksheets we created new sample solutions for the two tasks from Biehler et al. (2011). As a result of this introduction phase the MMTs gave the feedback that learning and using two digital tools was too heavy and they were more interested in learning to use Fathom. So we concentrated on Fathom for the rest of the course. As one reaction we guided a master student to develop an online video-tutorial for our Excel-worksheets in his master thesis. For the topic Data: Where from and What for? we introduced GoogleDocs and its questionnaires features. We gave a short introduction for using this feature and linked a Youtube-video as a tutorial. We also prepared GoogleDocs forms, where the MMTs collected their questions to develop their questionnaire for the data-analysis project. In addition we talked about relating research questions to questionnaire questions, and the organization of the data in spreadsheet programs. One pitfall, we hadn't been aware of before, was the non-synchronous edit-mode of the then latest GoogleDocs version concerning the questionnaire feature. If one user edits the questionnaire no one else should edit it because the changes would be overwritten. Since January 2013 the questionnaire feature has a synchronous edit-mode, so this pitfall is fixed now. In the third topic Representing, summarizing, and interpreting data we discussed some digital learning environments for exploring the different properties of arithmetic mean (mean as fair share, difference to the mean balance out to zero, sum of absolute deviations of values higher than mean is equal to the sum of absolute deviations of values lower than mean) and for exploring the robustness of the median as compared to the mean. Another issue was the characteristic of the box plot following Tukey, which Fathom is using, as compared to the basic box plot (with whiskers drawing to the extreme points), which most German textbooks use. At this point most teachers felt problems for their teaching, as the software uses another variant of the graphical representation as the textbook does. During the topic Trends and relationships in data we discussed the aspect of signal and noise in analyzing the association of two numerical variables. We addressed the drawing of a line with good fit with three approaches: (1) drawing in a line of good fit by eye-balling (2) drawing in a line of good fit by hand supported by an additional graphical representation of the residuals and (3) drawing in a line of good fit supported by a graphical representation of the residual squares. We also discussed the option of using sliders for moving the line of good fit, which supports the understanding of linear functions. On the other hand we discussed how to use Fathom to compare two distributions of numerical variables. We introduced dividers and their numerical and graphical calculation in Fathom as well as displaying multiple box plots in one graphic window. The fifth topic Critical dealing with statistics and data in the media was split into two aspects. The first aspect dealt with the use of official data, for example provided by the Federal Office of Statistics and how these data can be analyzed by using digital tools to work on interesting questions (e.g., Krüger, 2012). The second aspect concentrated on newspaper articles that deal with the relation between two categorical variables and the typical misconceptions concerning these relations (confounding row and column percentages, respectively different kinds of conditional probabilities). The different contingency tables needed to be calculated using Fathom. In the last topic Statistical projects and presentations with digital media we discussed a best-practice example for a data-analysis project to be worked on by students in school. The technological aspects that were addressed here dealt with the preparation of reports or presentation of the results by the students. Besides, the question of how to introduce a new digital tool in classroom was discussed.

We in our role as course designers used digital tools, especially Fathom, in different ways. Retrospectively we can identify four ways of using digital tools in our activities: (1) Digital tools were used for demonstrating properties of statistical concepts like the properties of the arithmetic

mean or the robustness of the median as compared to the mean. (2) Digital tools were used for exploring different approaches of using digital tools in classroom. One example for this meta-activity is the exploring of three different ways of determining a line of best fit as described above. The MMTs tried out each of the three ways in a learning environment and had to discuss about the pros and contras of the three ways. (3) Digital tools were used to increase the interactivity during a talk, especially during the online-meetings. As one example we discussed the paper-folding-task from Kamischke et al. (2007, p. 207-209). The MMTs, sitting at home in front of their computers, had to do several measurements on their varying triangle and had to fill out a GoogleDocs form with their measured lengths. After finishing the task we had each measured length in one GoogleDocs spreadsheet, copied the results into Fathom and analyzed the data during the online session. (4) After the second meeting we recognized that the MMTs needed more time to get familiar with Fathom and we introduced Fathom-lessons to compensate this and to increase the MMTs' tool competences. The MMTs had to solve some tasks that were related to the current topic and needed to be solved by using digital tools. With these activities we deepened the MMTs' Fathom-competences.

Besides, for the SPDCs each group decided to focus on the introduction of Fathom as a digital tool for teaching data-analysis. This shows that the MMTs have the ability to teach the use of Fathom during a teacher training.

REFLECTION OF THE MENTOR TEACHER COURSE CONCERNING THE USE OF TECHNOLOGY

Based on our experiences during the CPD, especially the discussions we had with the participants, the experiences acquired during the short teacher professional development course, the participants organized at the end of the course, and in-depth interviews, the first author made with each of the thirteen participants three month after the course and after the SPDCs, we will summarize basic findings concerning the use of technology in our course. A systematic analysis of the interviews will be done in the Ph.D. thesis of the first author. We identified two main aspects concerning the use of technology that we will discuss in the following.

The first aspect deals with the valuation of Fathoms strengths for teaching statistics. In the interviews the MMTs emphasized two facets: 7 MMTs stressed the efficiency of Fathom, for example, for plotting a graph. In comparison to Excel the time to get a reasonable graph in Fathom is much shorter. 6 MMTs underlined using Fathom as a tool for dynamic interactive visualizations, for example, for demonstrating the robustness of the median as compared to the mean. Some MMTs have not known these possibilities before and they saw an important additional value of using Fathom: "For example using Fathom for demonstrating the behavior of mean and median. That was incredible! I remember a lesson, where I stretched my limits, because I had no further ideas to explain this to my students. That was so obvious that I said 'Oh my god! Had I known this before.' This lesson would have been much better!" (Translated by authors). It is noticeable that, for example, Fathom strengths concerning plotting and linking multiple graphs at once on the same scale and adjust them dynamically (Biehler et al., 2013) was not explicitly mentioned.

We have to be aware that the conception of a digital as an instrument that is constituted in the process of instrumental genesis (see Guin & Trouche, 1999) differs considerably between the organizers of the CPD and the participating MMTs and there is much variation between the MMTs. This difference is pretty "natural" but the difference turned out to be larger than expected. One of the reasons is that the MMTs had unexpected little experience with using digital tools in the classroom at all. We also saw a difference in the MMTs' practice of using Fathom in practical work and how they can explicitly explain the specific features of Fathom as compared to other tools. This is usually not a problem for MTs but MMTs in their role of organizing professional development courses for teachers themselves need to have TPCK in a much more explicit way. For a revised version of our CPD we will have develop an explicit guide for comparing different tools available for data analysis at school level. This guide should contain explicit dimensions of comparison that can be adapted from the literature (Biehler et al., 2013) and that are illustrated by different tools in action on examples. This would also support the MMTs in their practical work with other teachers and schools who require their advice in choosing tools. Another interesting aspect of the discussion about the strengths and limitations of Fathom were differences between

concepts and notational conventions between a digital tool and the textbook introduced in school as well as the everyday practice of teachers. Our MMTs mentioned the limited possibilities of relabeling the axes as a negative point especially in comparison to the thoroughness the students are asked to draw a graph by hand in typical classrooms. The definition of box plots in Fathom (definition of the quartiles, Tukey vs. basic box plots) was another case in point. Also the default setting of axes is different from classroom conventions such as that a scatterplot should have equally scaled axes or the point (0,0) should always be part of the graph. This however is a general problem with introducing general digital tools in the classroom, which cannot be resolved. This is only “solvable”, if interactive material is integrated in a textbook series as supplementary material, which is adapted to the notational systems of the textbook.

The second critical aspect, we like to point out, is the sustainability of tool competence, when a digital tool is not used continuously every week over a longer period of time. Statistics and probability will cover at most 3-4 weeks every school year and it is of course a fundamental question whether learning a specific tool just for these periods is worth the effort. Spreadsheets and tools such as GeoGebra are used in other mathematical topics. This can be seen as an argument to use these tools for statistics as well. On the other hand there are very specific commands, options and use patterns in these general tools that have to be learned just for use in statistics, which counterbalance the advantages. Although the MMT’s Fathom competences, we observed during the CPD and during the MMTs SPDC, were satisfactory on average from our point of view, the MMTs expressed a lot of uncertainty about their Fathom competence when they were interviewed. The uncertainty includes the knowledge about some specific features of Fathom like the different effect of using filters for collections, graphs, tables or summaries and also some features of Fathom that we discussed but we did not focus on, like the different percentages (cell, row and column percentages) or using residual analysis fitting a line to data. Some of them consider this as an obstacle for using Fathom in their classroom and in their teacher trainings.

Several different interpretations emerge. First of all, using any kind of digital tool in the classroom will increase teachers’ uncertainty, because moderately complex tools can never be mastered as well as other more conventional and simple tools. There is always a risk that some students know more than their teachers do or that a teacher cannot answer more advanced questions students may pose. We have wrongly assumed that our teachers have had such an experience with other digital tools and had successfully overcome this initial uncertainty so that they can transfer this to the use of Fathom. As this was not the case, we have to think more hardily in the future how we can support the transition from use of a digital tool for themselves to implementing it in classroom settings. In the course itself, we started with the first topic Introduction to data-analysis with digital tools, where the MMTs learned the basics of Fathom with the multimedia and video-based tool eFathom and two tasks from Biehler et al. (2011). Moreover, we integrated so-called Fathom-lessons to maintain and extend the level of Fathom competencies continuously during our course. Although these introductory materials remained available to the MMTs, they expressed the need for different more quickly usable material for reviving the Fathom competence. An option, that was explicitly mentioned by some MMTs, is to design short reference cards for several relevant Fathom tasks by the MMTs themselves as another activity for increasing T(P)CK. In contrast to the existing introduction to Fathom basics in Biehler et al. (2011), where the needed basics are discussed in a continuous text on two to three pages, these short cards are designed as a recipe: a brief step-by-step manual for certain tasks like “How to produce the different contingency tables and the corresponding bar charts?”. The pedagogical function of these short reference cards is not for learning these functions and solving tasks but to give the user a reminder to them. This could be a possibility to decrease the effort for re-learning Fathom (or other digital tools in general). A third interpretation our observation is the following. Fathom is a pretty complex tool, ranging from applications in high school to college level. Experienced digital tool users find their way into such complex tool and are aware which features they know and can use whereas they put others aside. A newly designed learning path should address this strategy more consciously so that the MMTs are more aware of what they can do with the tool or what they can’t do. However, it may be also the case that complex tools such as Fathom are too complex for convincing average secondary teachers who have to meet many demands in various domains in mathematics and with many other digital

tools and therefore are not willing to invest the necessary learning time and take the emotional risk of such an endeavor.

When we have analyzed all our data and redesigned the CDP course we will report on new experiences.

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